European Project Semester

Foundry process

JOSMD EPS FOUNDRY

Final Report

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Abstract

This document is a report on the work completed in the Foundry process team, between the months of February and June 2016-2017, at the École Nationale d'Ingénieurs de Tarbes (ENIT), as part of the European Project Semester (EPS). Five students from different countries have been working together in a team on a technical project, managing it with several management tools which you will find out during this report. These objectives have been achieved with the help of several supervisors.

This team had the task of coming up with two handbooks for ENIT students, the first one explains different foundry processes, which are sand casting, lost wax and die casting. Finally, the second describes tensile tests and metallurgical tests.

To achieve this goal, studies had carried out by the team to gain the necessary knowledge to understand the different process, discuss how to teach them and develop designs about the different parts we have been casting. Once the team had enough information about the diverse processes, we started using our skills as designers and engineers to develop the designs, evaluating the pros and cons of each design and find out which one is more interesting for every casting method. Once this design was approved by the technical supervisors, was transferred into a CAD design with the software CATIA V5 for creating the different molds and after casting in the laboratory, we had all the knowledge for writing the handbooks for the ENIT students.

Acknowledgements

We would like to thank to all the staff at the ENIT for making our time here as enjoyable as possible. We have been given guidance every step of the way, making living in Tarbes a very pleasant experience.

A special thank goes to our technical supervisors Francois Grizet, Yannick Balcaen and Guillaume Mazenc, as well as our management supervisor Philippe Fillatreau for their advice and guidance on the project so far. We would not be able to complete the project without them.

We would also want to express our greatest gratitude to all the teachers and colleagues from the EPS for all their help and support during these months.

1. Abbreviations

CAD	Computer Aided Design
CATIA	Computer Aided Three-dimensional Interactive Application (software used for creating the computerised design of the parts)
ENIT	*Ecole Nationale d'Ingénieurs de Tarbes**
EPS	European Project Semester
MGP	*Mécanique Générale de Précision** (French company for manufacturing the die casting mold, the translation in English means literally mechanic general of precision)
MS project	Microsoft Project
WBS	Work Breakdown Structure
BC	Before Christ

*Letters in cursive are words in French that cannot be translated because are nouns.

Content

2. Context

2.1 Introduction

The project is developed within the framework of the European Project Semester program at the École Nationale d'Ingénieurs de Tarbes (ENIT). EPS takes place at 18 different European universities spread around 12 countries. It is geared towards engineering students and uses a mixture of 'Project Related Courses' and project organisation based learning. The students on the EPS are divided into international teams who work together on a technical project.

The program is run by the students themselves; they learn how to take responsibility for their own learning and project work, assuming knowledge in technical and management things. The project must be managed as professionally as possible, with the results displayed in presentations and reports. English is the language in which EPS is developed and ideally each team must be multinational and multidisciplinary. The aim is to promote the teamwork of international students.

It started with the proposal by the teachers of developing learning guides to teach future students of the ENIT the different casting processes and tensile tests on a practical way.

The foundry project started on 27th February 2017 at l'Ecole Nationale ďIngénieurs de Tarbes (ENIT) in Tarbes, a city in the southwest of France, and will end on the 30th of June 2017.

2.2 People involved

2.2.1 Students

The EPS foundry process project group consists of 5 students from 4 different countries, cause our different nationalities we must speak in English. In the next figure, you can find out our country and a little bit of information about our type of bachelor's studies and university:

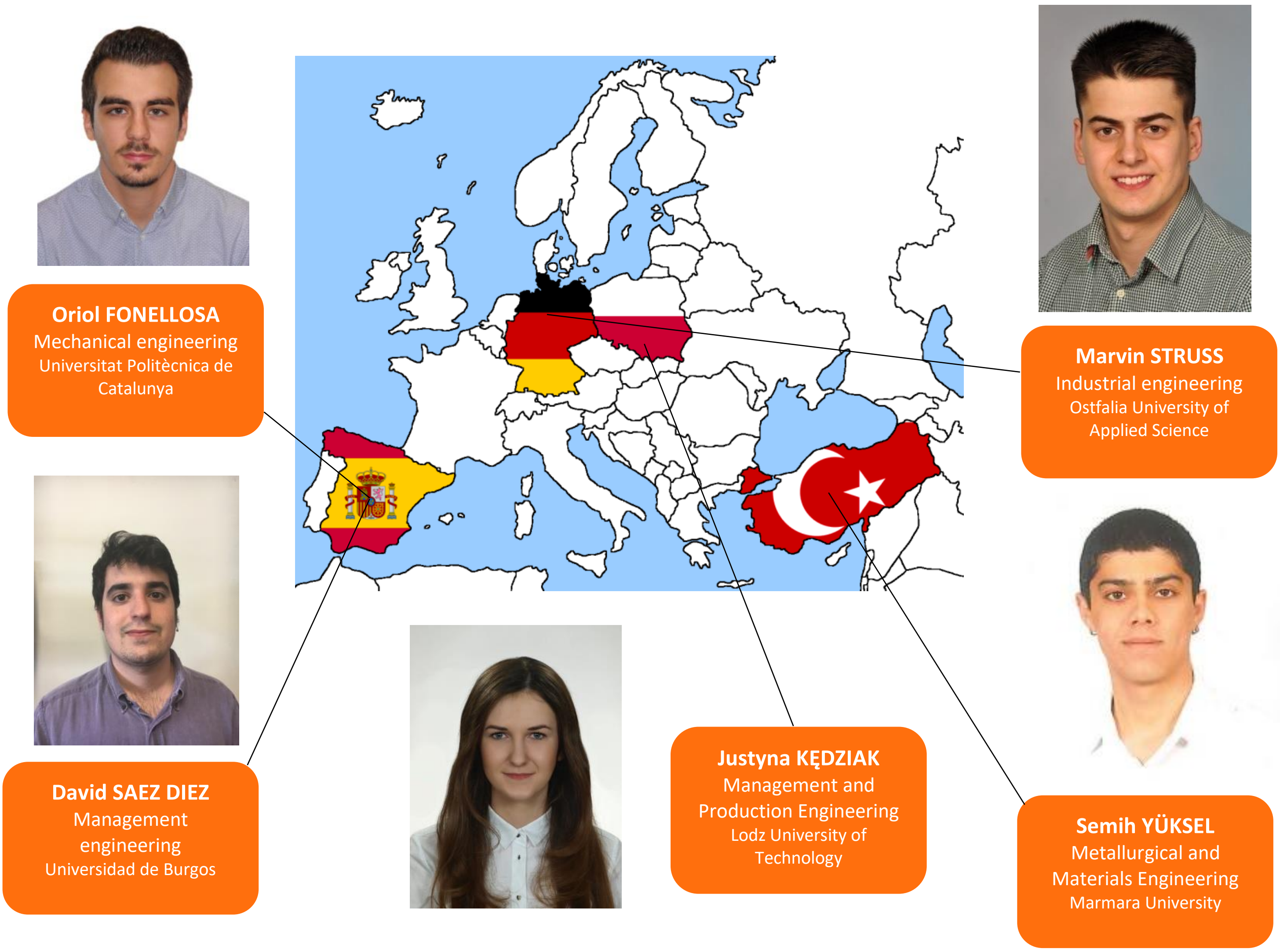


Figure 1: Map of student's origin

2.2.2 Supervisors / Clients

As part the EPS program we have supervisors that can help us during the project, in our case we have three technical supervisors and one management supervisor. Our technical supervisors are:

2.2.2.1 Technical supervisors

Francois GRIZET
Computer Assisted Design

Yannick BALCAEN
Materials Science

Guillaume MAZENC
Manufacturing Processes

As a management supervisor, we have:

2.2.2.2 Management Supervisor

Philippe FILLATREAU
Project Management
Associate Professor, Vision Systems, Virtual Reality

We have two main clients, who are two of the three technical supervisors. This situation occurs because we are designing two handbooks for the students, meaning that our clients are the teachers of those students. Finally, we can also say that the ENIT and their students are our general clients and these are our main clients:

2.2.2.3 Project Clients

Yannick BALCAEN
Materials Science

Guillaume MAZENC
Manufacturing Processes

Also, we have other stakeholders that we think are important to be known:

2.2.2.4 Additional Stakeholders

Baptise TRAJIN
EPS coordinator

2.2.3 Tools

As a group, we have been using EPS room EniOne which is in the building C of the university (as seen in figure 2 below). Additionally, we have worked in the ENIT's Laboratory of Manufacturing Engineering for casting and testing the different steps of the project. In the next map, you can see the different locations:

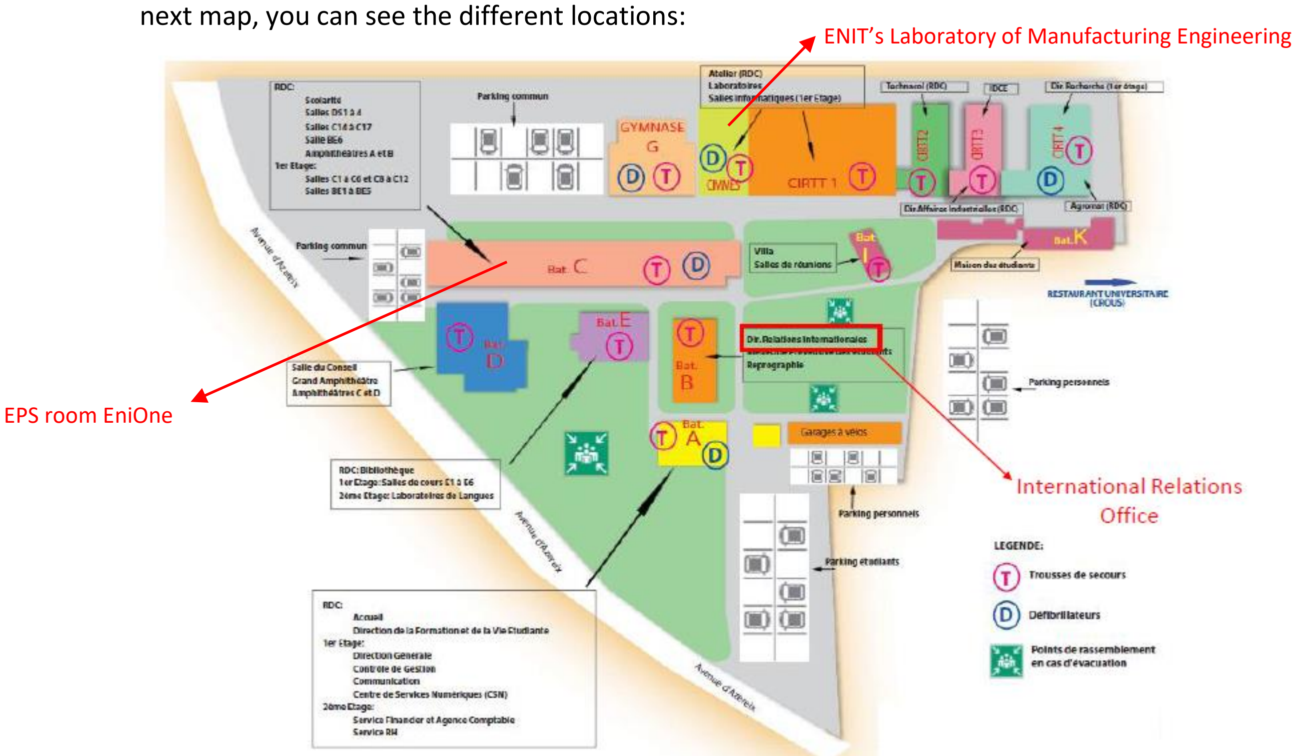


Figure 2: Map of the ENIT

2.3 Needs expression

As EPS students, we have been asked by our clients, who at the same time are teachers of theoretical and practical lessons in the Laboratory of Manufacturing Engineering ('LGP' Abbreviation is in French) to design two handbooks for explaining two different practical lessons. The LGP laboratory is a research facility at the ENIT, one of its aims is to teach students about foundry processes and the different tests you can do later, for example tensile tests or metallurgical tests. Currently, the students have knowledge about the subject because during the first semester of their bachelor degree they have theoretical classes about this subject, that's why our clients have asked us to create these handbooks, because they need a practical class in the laboratory for consolidating that knowledge.

Figure 3: LGP logo

Foundry processes have been probably one of the oldest process in our history, this method have been used for a lot of years and there are different types of casting for creating a new part, the way to select the best foundry process for that part depends about many things, the price, the shape, how many times are you going to cast the same part, which is the quality you want, and other important things we are going to deal in this report. In main words, we must cast three different methods to create a practical class for the university students.

The aim of this foundry process project is to teach engineering students at the ENIT how casting works. We have the task of designing two handbooks for being a tool to follow a practical class. We are going to use different tools from the LGP laboratory that has been given to the project group for using them, for example we will use a furnace as the heat source for melting the aluminium and some other machines for other tests that you will find out in the *machines* part in this project. The design will be presented in the form of technical drawings and inputted by the team into the engineering software Catia.

2.4 Document outline and organisation

The rest of this document can be broadly separated into five main categories.

Chapter 3, scope, describes the scope of the project, with the project objectives and deliverables. This was decided with our clients and supervisors during the first stage of the project.

In chapter 4, technical, we have described our process and thoughts that have lead us to the final technical solution. This section describes our design and development process and gives a description of the final technical solution.

Chapter 5, management, describes how we planned the project with regards to task distribution and management. Also, is explained all the steps we took to monitor the project to ensure all the tasks were completed on time.

Finally, in chapter 6 we conclude this report with a final assessment of the project, what we could have done better and what we learnt from the project. The report finishes by explaining the state we have left the project in, and what we predict will be the next steps in the foundry process project.

For last but not least, in chapter 7 there are our conclusions for the project summarising all the work we have achieved and the knowledge and good experience we have now.

3. Scope

In this chapter, the scope of the project is established. It defines the project range along with the project objectives and deliverables, who is involved, which tools are available and every other aspect of the project.

3.1 Objectives

Our main objective in the foundry process project is to create two handbooks for practical classes which are going to be done in the ENIT's laboratory. The first handbook is for bachelor students and the second one for master students. In the first case, we must create a practical guide step by step for an eight hours session, where bachelor students are going to try two types of casting: lost wax and sand casting. These two different types of casting are going to be explained during the technical part of this report. In the second case master students are going to do a metallurgical test with the standardized parts that the bachelor's students have casted earlier during their practical session, these test is going to last for two hours, in the technical part of this document you can find out the explanation of this process.

In the bachelor guide, as we have said, the students are going to do three different types of casting.

In the first one they are going to use the lost wax method and they are going to cast a goodie. This goodie is for the ENIT university and the supervisors or the responsible teacher of the practical class will decide about what to do with the goodie. Our client told us that the lost wax goodie should represent the University and as you will see during the report it represents the university.

In the second casting method, students are going to cast with sand casting process with the aim of obtaining twelve different goodies, which they could keep as a gift, finally they are going to cast also three regulated parts, which are going to be used by the master students.

Finally, in the master student's handbook, the students carry out metallurgical analysis tests with the three testing parts from the sand casting process. With the results of the testing, they are going to find out if the tensile part (the standardized part casted during the sand mold process) have imperfections due the casting or not.

To obtain the two handbooks, we have developed all the steps of the process that the students have to follow in the laboratory, in the same situation as the students. Finally we have defined the activities that should be done in the practical sessions following the handbook.

During our practices, we have obtained some physical parts (defined deliverables section) that we will be deliver when the project is done.

3.2 Risks

In this part, we are going to discuss about the different risks we have in our project, we are analysing which are the solutions to those risks in case they appear during the project.

3.2.1 Risk Matrix

For analysing the different risks that could appear, we have used a matrix created by NASA and defined at the ISO normative. In this table, you can check out different categories depending on the impact we categorize them. First, we are going to talk about the three different impacts that we have; minor, moderate and major sorted from less important impact to more important impact. The categorization with like hood it's about; likely, moderate and unlikely and this time sorted from more possible to less.

Secondly, we are going to explain why we are using three different colours inside the matrix, you can check out green for low risks, yellow for moderate risks and finally red for high risks. We think that with colours it's even easier to understand our risks matrix.

Finally, we are going to describe the different risks we have listed, notice that we have split them in two big sections; Management risks and Technical risks

3.2.1.1 Management risks

1) Inaccessibility of a team member.
2) High cost (process, materials).

3.2.1.2 Technical risks

a) Failure about building a wax model by any method available. There are two methodologies available for 3D printing in wax.
b) Cannot build the lost wax process mold.
c) Cannot manufacture the sand casting process part.
d) The die casting mold will not be on time.
e) Do not have enough time to cast all the parts because problems with the machines in the laboratory during processes.
f) The casting processes take too much time to be done in a practical lesson.
g) 2 clients (possible needs expression conflict). Cannot manufacture the die casting mold.
h) Not be able to manufacture the different samples in polyurethane.

i) Inability of the machines in the laboratory.

Now, we can apply these different risks in our matrix:

		IMPACT		
LIKEHOOD		MINOR	MODERATE	MAJOR
	LIKELY	MODERATE d	HIGH	HIGH
	MODERATE	LOW f	MODERATE 2, b	HIGH i
	UNLIKELY	LOW 3, h	LOW 1, a	MODERATE c, e

Table 1: Risk matrix

A risk matrix is an extended used method at risk assessment process. This matrix was developed starting the models used by the United States of America Department of Defence and the NASA, and the also defined at the ISO normative. After the supervisor advice, the matrix was simplified, giving rise the current matrix.

We want to notice that the risk d), which is about not having the die casting mold on time has happened but as we said at the first time this is a likely risk but with a minor impact and it's like and our clients agree with that. We are happy to show that our matrix is actually working as expected. We will discuss more about our deliverables achieved during the point 3.3 Deliverables.

We think that also is very important to solve that risk if they appear, so in the next point we are going to discuss about the different solutions to the risks.

3.2.2 Solutions to the risks

According to the same list that is shown in the las two points:

1. If one of the members is not able to come one day, that person is going to make up for those hours lost. In case one member is not coming for more than one day we are going to distribute the work of that person between the other members, meaning additional 6 hours splitting them between the 4 members that are working.
2. We will discuss with the technical supervisors the way to make the cost lower.

a) We have two different methods for printing in wax, the first one with a filament of wax and the other one with a resin. If any of the two methods we know can be printed, we will study other possibilities because this process has never been done at the ENIT but it has been done in other places, so we know it's possible.

b) We will check for another method for creating the mold with the wax, changing the plaster which is the material around the wax when it’s inside the mold or even trying to change the sand.

c) If it’s difficult to manufacture the part in polyurethane we are going to leave it like it has been printed, it’s not the same quality but our clients think that it’s more than enough.

d) There is no big problem if the mold for die casting is not on time because our supervisors could manufacture it with our CAD files.

e) According to our technical supervisors as soon as we deliver all the CAD files they can cast and manufacture all parts are needed.

f) There is no problem if practical lessons are a little bit longer, we can even propose to do the practical lessons in two or three days with a maximum of eight hours in total for all the different days that we have divided the class.

g) In this situation, we must deal with different opinions and then make an agreement of what we think is better.

h) An external company (MGB) could manufacture this mold if we are not able to do it at the ENIT laboratory.

i) In case any of the machines get broken, we are going to try to repair it if it is possible, if not we will have to wait until the supervisors repair it.

3.3 Deliverables

In this part, we can check out the different deliverables that we are going to give to our clients. At first, we had a more deliverables than those we are going to deliver at the end of the project because, for example we haven't been able to manufacture the die casting mold because we ran out of time.

To make it simpler, we are going to compare the deliverables that we had at the midterm report and those we have now and then the explanation of all the changes:

DELIVERABLES	
Deliverables in the beginning	**Deliverables on the final**
Handbooks	**Handbooks**
D.3.1 Bachelor's handbook (About lost wax, sand, die casting methods)	D.3.1 Bachelor's handbook (About lost wax and sand casting methods)
D.3.2 Master's handbook (About tensile and metallurgical tests)	D.3.2 Master's handbook (About metallurgical test)
CAD files	**CAD files**
D.1.1.1 CAD files of the goodie for lost wax	D.1.1.1 CAD files of the goodie lost wax
D.1.2.1 CAD files of the models for sand casting	D.1.2.1 CAD files of the models for sand casting
D.1.2.2 CAD files of the mold for sand casting	D.1.2.2 CAD files of the mold for casting
D.1.3.1 CAD file of the mold for die casting	D.1.3.1 CAD file of the mold for die casting
Physical parts	**Physical parts**
D.2.1.1 Lost wax goodie in wax	D.2.1.1 Lost wax goodie in wax
D.2.1.2 Sand casting goodie and three testing parts in Polyurethane	D.2.1.2 Printed model sand casting goodie and three testing part in 3D printer
D.2.2.1 Die casting mold in steel	
D.2.3.1 Lost wax goodie casted in aluminium	D.2.3.1 Lost wax goodie casted in aluminium
D.2.3.2 Sand casting parts casted in aluminium	D.2.3.2 Sand casting parts casted in aluminium
D.2.3.3 Three testing parts casted in die casting	
Documents	**Documents**
D.4.1.1 MS project files	D.4.1.1 MS project files
D.4.2.1 Middle term report	D.4.2.1 Middle term report
D.4.2.2 Final report	D.4.2.2 Final report

Table 2: Deliverables, beginning versus final

3.3.1 Handbooks

Bachelor's handbook, a handbook describes step by step the types of castings to be made in the practical casting class in the bachelor level. At the beginning of the project, die casting will also be found in this handbook. However, we have not been able to experiment with this casting method since we are too late to prepare die mold and we do not have as many experienced people with knowledge in die mold, even our supervisors. For these reasons, at the end of the project we pulled this casting method out of the handbook.

Master's handbook, a handbook describes step-by-step the tensile and metallographic testing to be done in a master-level laboratory. At the beginning of the project, it was decided to include the tensile test in this handbook. However, we could not try this test because the tensile testing machines were broken and we decided with our clients that it was not right to attach a process to the handbook that we had not tried before. At the end of the project we removed this test from the handbook, leaving it just with the metallurgical test.

3.3.2 CAD files

CAD files of the goodie for lost wax, the part to be produced by lost wax casting method is designed in CATIA.

CAD files of the models for sand casting; Models to use in sand casting designed in CATIA. These models are the goodie and tensile test parts.

CAD files of the mold for sand casting; Models to prepare sand mold designed in CATIA. These models contain feeders and risers for goodie and tensile test parts that we use in sand mold.

CAD file of the for die casting; Mold design with CAD program containing tensile test pieces to be produced by die casting method.

3.3.3 Physical parts

Lost wax goodie in wax, the goodie that will be produced by lost wax casting method is printed with 3D printer with wax.

Sand casting goodie and three tensile testing parts in polyurethane; Models in polyurethane for sand molds to be prepared for goodie and tensile test parts. At the beginning of the project we decided to use polyurethane. But then we experienced that the models printed on 3D printers were handy and we decided to print them on the 3D printer.

Die casting mold in steel; The mold type we decided to use to produce tensile test pieces. However, due the fact that we did not have enough time and experience to produce this mold during the project period, we decided with our clients to remove it from the deliverables.

Lost wax goodie casted in aluminium; Part produced by lost wax casting method.

Sand casting parts casted in aluminium; Part produced by sand casting method.

Three testing parts casted in die casting; Parts produced by die casting method but we had no time to try this casting method and then we decided with our clients to take this deliverable out of our list.

3.3.4 Documents

MS project files; Files we prepared for project management.

Middle term report; The report we prepared for the midterm in the EPS.

Final report; The report we prepared for the final in the EPS.

3.4 Exclusions and limits

We defined our limits and exclusions about the project during the first weeks with the agreement of our clients and supervisors in the requirements document which is in the appendix of this report. First, we are going to talk about the exclusions that we have in this project:

3.4.1 Exclusions

- In the project, we won't do a guide for teachers, just the handbooks for students.
- We won't translate the handbooks into French. We will only deliver guides in English.
- We are not going to print all the lost wax parts, just the first one.
- Just one goodie created during lost wax process because of the price of the wax for printing in the 3D printer.

3.4.2 Limits and priorities definition

During our project, we have defined two different plans, plan A and B in case we were not able to achieve all our objectives we could move to the B plan. So according with the clients and supervisor's advice we can define which deliverables have a higher priority than the others and in case of a contingence plan, (plan B) define what task accomplish and which not. In the next table are defined the mandatory and optional deliverables:

MANDATORY	Handbooks for bachelor students (D.3.1.1, D.3.1.2, D.3.1.3) Handbooks for master students (D.3.2.1, D.3.2.2) First lost wax part (D.2.1.1) CAD model for lost wax goodie (D.1.1.1) 3 tensile test samples and 12 goodies (from sand casting) (D.2.3.2) 3 tensile test samples (polyurethane) (D.2.1.2) Sand casting goodie (polyurethane) (D.2.1.2) CAD model of the sand mold (D.2.2.2) CAD model for sand mold goodie (D.1.2.1) CAD model of the tensile test sample (D.1.2.1) CAD model of the die casting mold (D.1.2.2) CAD model of the tensile test sample (D.1.2.1) 3 tensile test samples (from die casting) (D.2.3.3) Management documents (D.4.1) Review package files (D.4.2)
OPTIONAL	Graphic documents for bachelor students (D.3.1.1a, D.3.1.2.a, D.3.1.3.a) Graphic documents for master students Die casting mold (D.2.2.1) Master part (D.3.2.1, D.3.2.2)

Table 3: Mandatory and optional deliverables. Plan A and B.

According to this table, plan A are the mandatory and optional things and plan B just the mandatory.

In our situation, we have stick to the plan B, because all the problems we had during the development of our project that we are going to explain in the next points:

First, we had problems with the die casting mold because we didn't have enough knowledge for doing all the calculations for the mold and even our technical supervisors had problems to know how to calculate them. Finally, we calculated all the parameters but we run out of time to manufacture the die casting mold but the CAD file is created and is going to be delivered to our clients.

Secondly, we had problems with the tensile machine for the master handbook. The problem was about the machine of the laboratory, which was broken during all the project so it was impossible for us to try the different steps of that handbook and finally we decided to avoid that part.

Finally, the last problem was about the furnace for melting the aluminium, first we had problems with the ventilation of the smoke created during the casting process and we had to wait for one week until we found a new place with a correct ventilation to cast in safe conditions. When we had the perfect location, the furnace broke down meaning that we couldn't cast again until the end of the project because the part of the furnace broken will be repair for the next semester.

Due to these problems, we had to move to the B plan.

3.5 Summary

This scope has been written by the project team and agreed on by the project clients and supervisors. It is important to properly define the project scope so that the project runs as smoothly as possible and the client is satisfied at the end of the project. Once these project parameters have been defined, it is possible to start developing the technical solutions for the project, which you will find out in the next point.

4. Technical

In this chapter, we will describe the research that was undertaken to gain understanding of the foundry process and the progression of the design including our initial thoughts and how we attained our final design. Our decision process has been outlined in this section. Finally, we will present our final results for the foundry process project.

4.1 Research

To begin this project, we researched the three different foundry processes, existing machines, and gained information on the properties of the aluminium used in the process. The research of existing machines and processes helped define the project scope and gave us a starting point.

First of all, we would like to explain a little bit about what's foundry and which are the origins and uses.

Foundry is the general name of factories that work with casting processes. Casting is one of the most used production methods in the world for creating metal parts. Firstly, the metal is melted and poured into the mold, then the molten metal is expected to take shape inside the mold and solidify after it has been shaped. After the solidification is completed, the formed cast part is removed from the mold in different ways letting you get the part you wanted to cast. The most commonly used casting materials are aluminium and cast iron with different configurations depending on the characteristics you want to get from that metal. There are foundry industries all around the world:

COUNTRY	TOTAL NUMBER OF FOUNDRIES
China	12000
India	4500
U.S.A	2620
Russia	1900
Mexican	1787
Japan	1713

Table 4: Total number of foundries by countries, article from Y. Ziya KAYIR posted on 2003

https://www.metalurji.org.tr/dergi/dergi141/d141_1824.pdf

The casting process has existed for thousands of years and it has been used especially in ancient times to produce precious jewellery, weapons for hunting and various tools. Nowadays, casting is used in every sector, from toy production to heavy industry.

The casting methods are classified according to the types of mold used. These types are:

- Expendable mold.
- Permanent mold.
- Others.

We are going to explain these different types of mold used with the following figure:

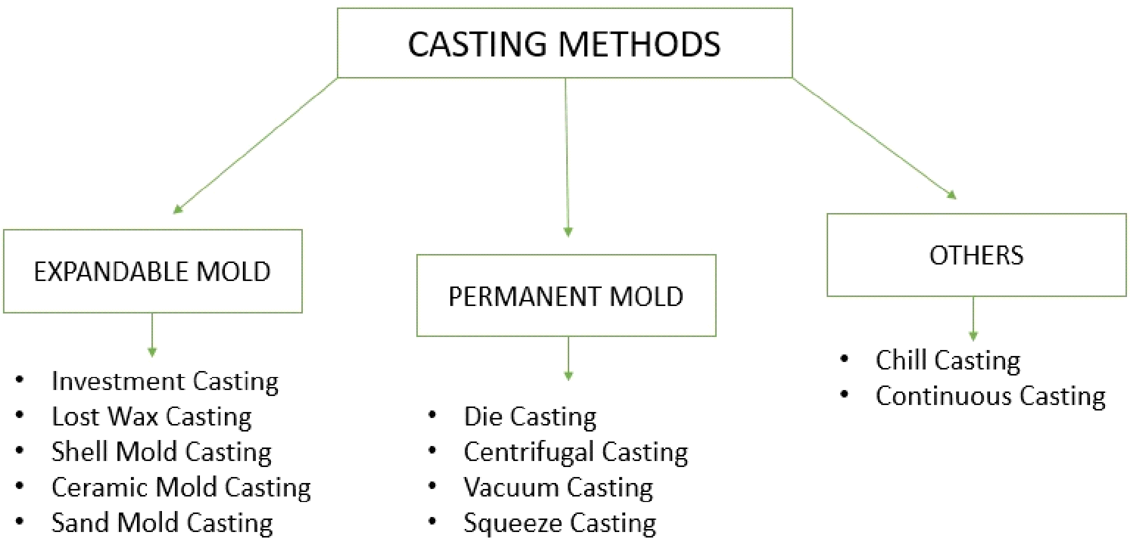


Figure 4: Casting methods

In the figure 4 you can see the three different casting methods and the type of mold that they use, also for the three different molds, are described all the methods where it is use.

Now, we know a little bit more about foundry process in a general over view but it is time to focus on the three different processes we are going to work with.

4.2 The processes

In this point, you can check out the three different processes. We have explained them in the most graphical and simpler way possible because even for us was a little bit difficult to understand.

4.2.1 Casting

In the following three points, we are going to explain the three different casting processes we are going to work with, they are explained in the clearest way we have achieved.

4.2.1.1 Sand casting

Sand mold casting is one of the most used and oldest types of casting method. In the following figure, we are going to show the different steps of the process:

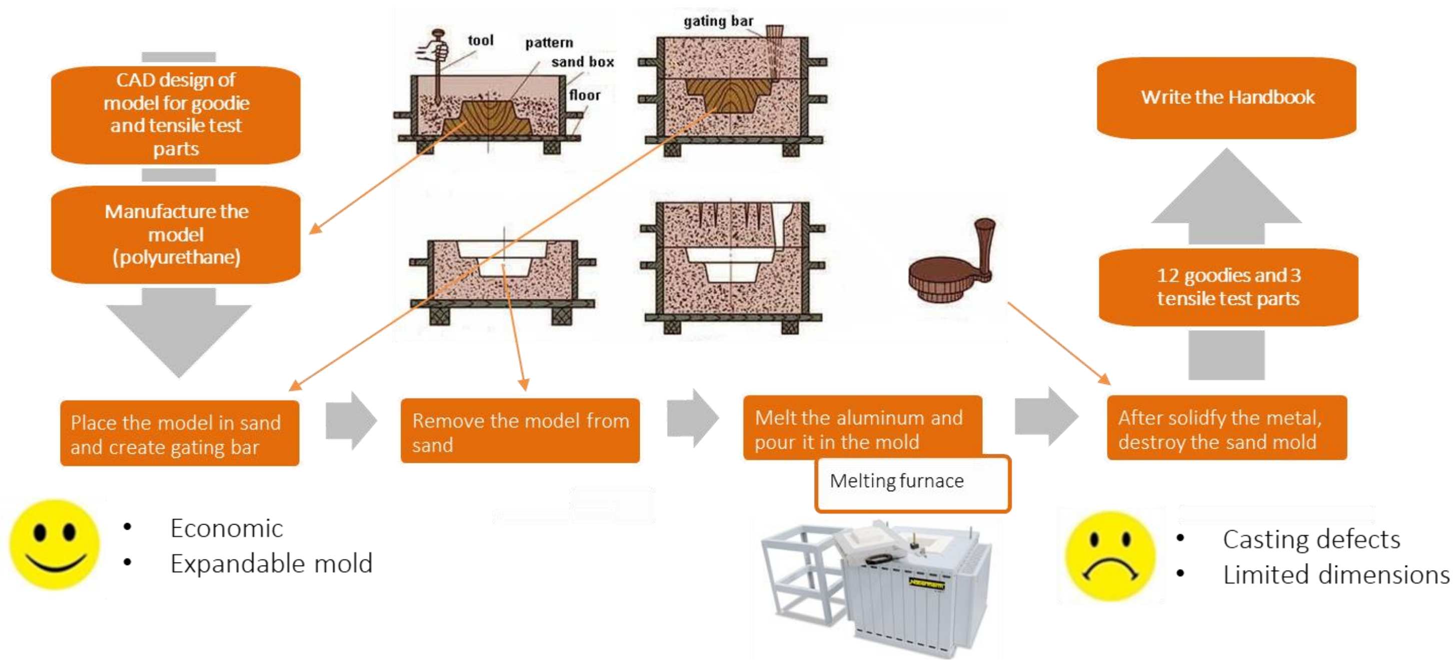


Figure 5: Sand casting process steps

In the last figure, you can check out in a simple and clear way all the steps in the sand mold casting process and also the pros and cons of the process.

4.2.1.2 Lost wax casting

Lost wax casting is a method of metal casting in which a molten metal is poured into a mold that has been with a wax part inside, later the mold is preheated and the wax is evaporated creating a mold with a cavity inside of the shape that the wax part had. These are the steps of the process:

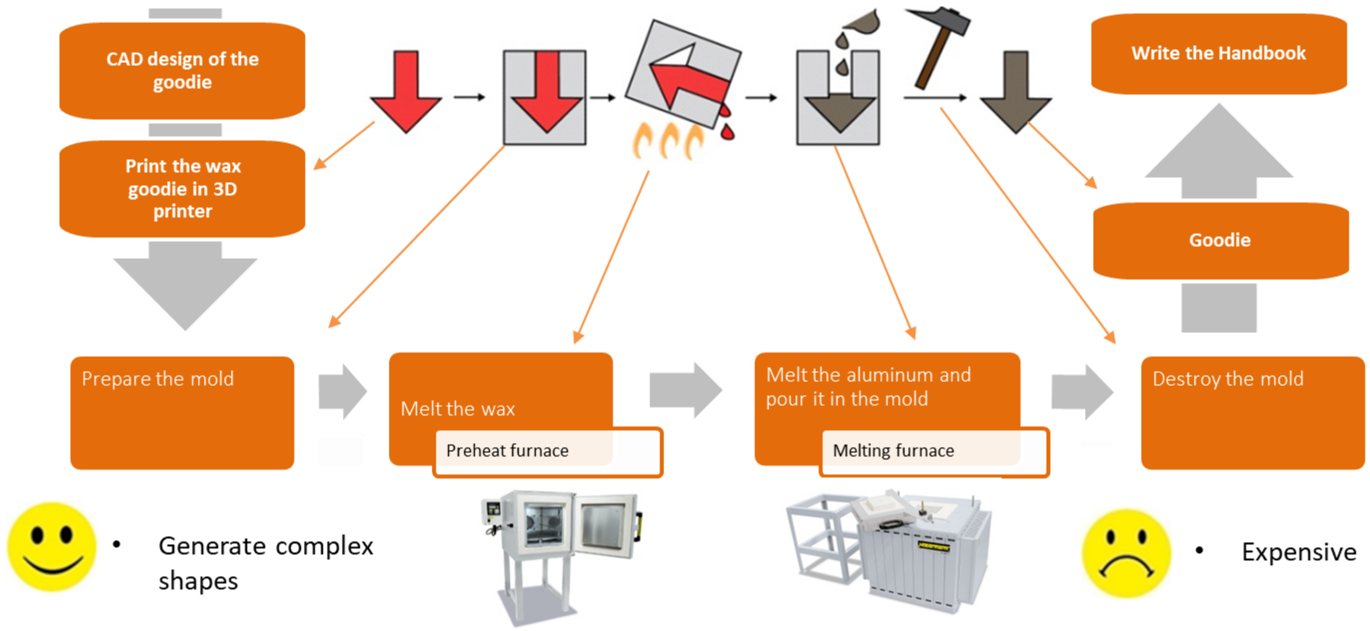


Figure 6: Lost wax process steps

Again, in the figure 6, you can check out in a simple and clear way all the steps in the lost wax casting process and also the pros and cons of the process.

4.2.1.3 Die casting

Die casting is a metal casting process that is characterized by forcing molten metal into a mold cavity. Die casting is usually made of hard tool steel. Generally, die casting is used for casting specifically zinc, copper, aluminium, magnesium, lead, pewter and tin-based alloys. Depending on the type of metal being cast, a hot- or cold-chamber machine is used.

As in the other processes we are going to explain the processes step by step with a figure:

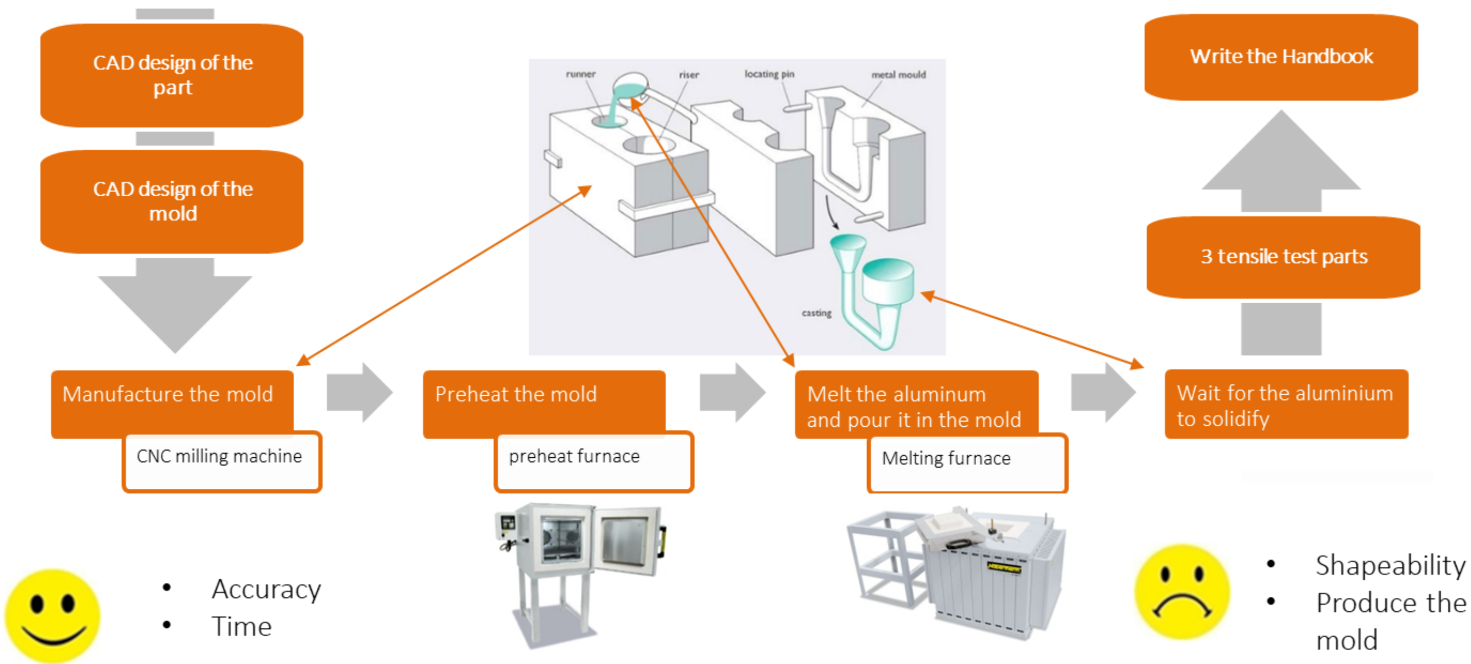


Figure 7: Die casting process steps

In the figure 7, you can check out in a simple and clear way all the steps in the die casting process and also the pros and cons of the process.

4.2.2 Quality tests

Tests to check whether the products obtained are in conformity with the standards defined from the ISO normative are called quality tests. In this project, there are 2 types of quality tests used.

In this project, we are going to work with two different processes, the first one is the tensile testing and the second one is the metallurgical tests, as later we are going to explain their steps in a simpler way:

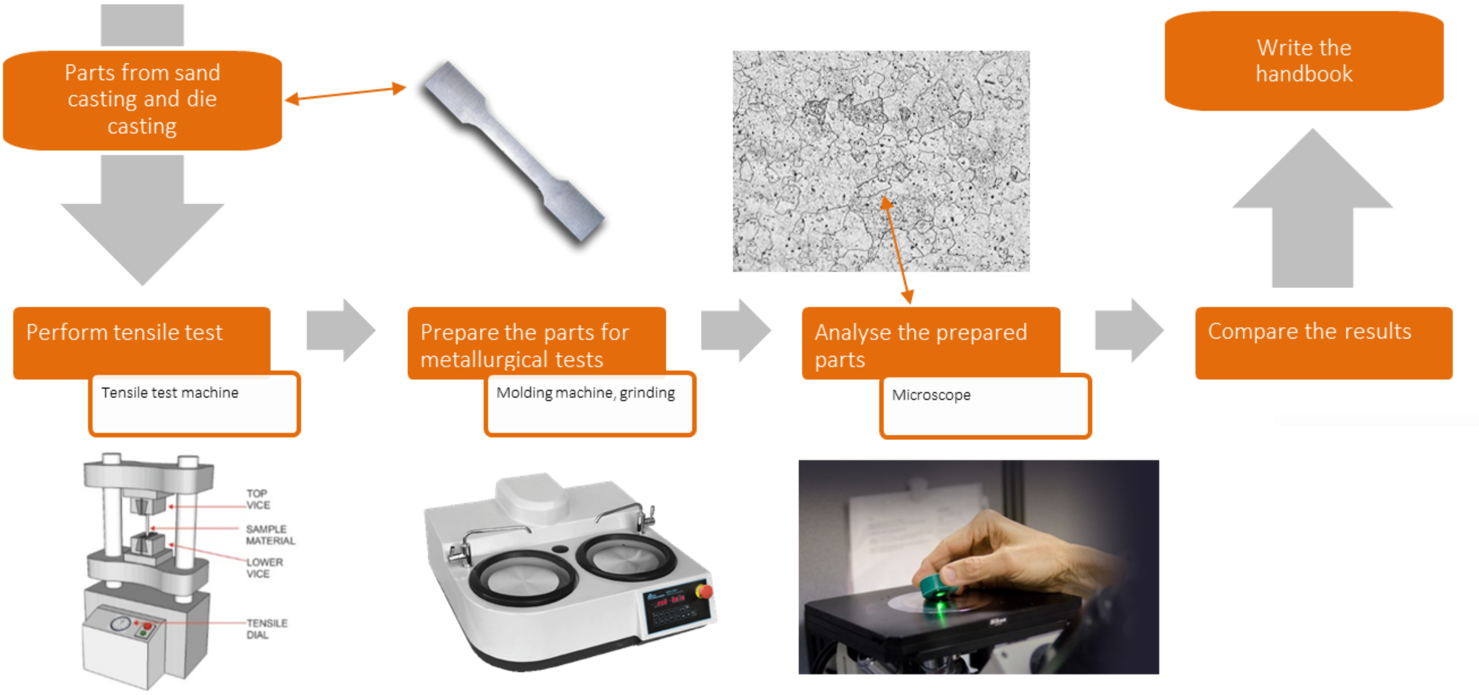


Figure 8: Quality tests steps

In the following two points, we are going to explain in a more specific way the two processes.

4.2.2.1 Tensile testing

A tensile test, otherwise known as tension test, is doubtless the most essential mechanical test you can perform on material. Tensile tests are simple, economical, and standardized. By dragging the test piece, it's possible to determine in what manner the material will react to the application of tension forces. Appreciating the elongation produced during the test, the strength of the material can be determined.

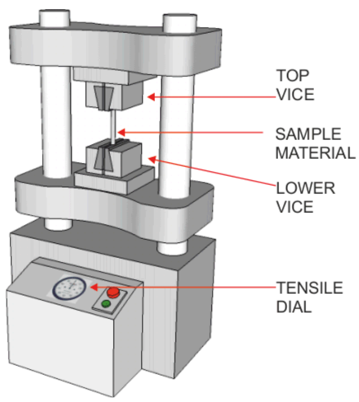


Figure 9: Tensile test machine

We can obtain a cluster of information directly through this test, for instance maximum tensile stress, maximum elongation and decrease in area. From these data, properties such as Young's modulus, Poisson's ratio, yield strength and consolidation can be obtained. The stress-strain graph can be generated as a result of these tests and the data result.

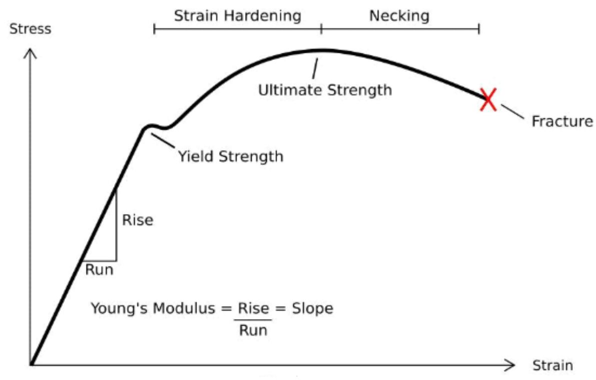


Figure 10: Stress-strain graph example

All these characteristics from the different aluminium's are known and registered so with your results during the test you can determine the type of aluminium you have and if it is and alloy or not.

4.2.2.2 Metallographic examination

Metallographic examination and analysis is a valuable source of information for any industry working with metals. A sample can be analysed with metallographic techniques to:

- Detect surface and internal flaws.
- Determine micro structural features.
- Evaluate heat treatments.
- Make sure the sample meet the required specifications.

The first step in metallurgical testing is test sample preparation. Samples are prepared in the LGP laboratory using precision cutting, mounting, grinding and polishing techniques, as well as etching when required. The second step is microscope examination of the sample.

All the steps are explained in a lot more detail in the master's handbook which you can find in the appendix of this report.

4.3 Comparison of the processes

According with the last points, the different processes that we have been working with have different advantages and disadvantages, in order to make it even more clear and simple we are going to show a table with the comparison of the processes:

Feature / Process	Cost	Shape ability	Accuracy	Process difficulty	Time	Risks
Lost wax	☹	🙂	🙂	☹	☹	☹
Sand mold	🙂	😐	☹	😐	😐	🙂
Die casting	😐	☹	🙂	🙂	🙂	😐

Figure 11: Comparison of the processes

All the different processes have advantages and disadvantages. It is not possible to say which process is the best one. The Lost wax process is the most accurate, because you can cast parts with a more complex shape due the fact that you are never going to open the mold again until you have cast, letting you create spiral shapes for example. With the lost wax process, it is feasible to cast shapes, which can't be produced by any other method. On the other hand, it is the most expensive because the wax is nearly 150€ for every litre of resin for printing and complicated process because you have then to melt the wax. It needs a lot of time to prepare the mold and perform the casting, as you will see in the handbook, you need nearly 5 hours for printing in wax, 1 hour for creating the mold, 2 hours for evaporating the wax in the furnace and half an hour for casting.

The sand casting and die casting are very similar in a lot of categories. After the mold for die casting is manufactured it is the easiest and fastest process compared with sand casting and lost wax casting. The costs of the die casting are higher than the costs of the sand casting process, because it is required to manufacture the mold with steel, before being possible to cast for the first time. The sand casting process gives a little bit more of shape ability, but the accuracy is worse. There is more risk in the die casting process because have to pay for manufacturing the mold and if anything is wrong with the design there is no returning way back, but in the sand mold casting there is the possibility to try many times because the sand can be reused without problem once have destroyed the mold.

4.4 Material used

For the casting, we have used always the same material which is an Aluminium with a maximum of 12% of silicon, also known has Al12Si.

This material melts at a temperature of 577ºC. These are the most important properties of the aluminium we have been using:

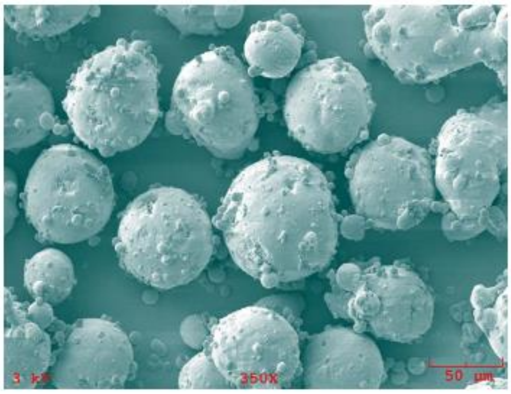


Figure 12: SEM photomicrograph of gas atomized Al 12Si powder

Thermophysical properties of AlSi12			Source
Density	2661	kg/m^3	[5]
Specific heat	0.939	kJ/kg.k	[5]
Heat of fusion	462	kJ/kg	Measured: DSC
Phase change temperature	577	°C	[5] / Measured: DSC
Thermal conductivity	181	W/m.K	[5]
Thermophysical properties of Mild steel			
Density	7854	kg/m^3	
Specific heat	1.169	kJ/kg.k	
Thermal conductivity	30	W/m.K	
ISO 100 quenching oil			
Density at 60 °C	890	kg/m^3	Measured: Lab
Specific heat at 60 °C	1.950	kJ/kg.K	Measured: MDSC
Kinematic viscosity at 60 °C	20.2	mm^2/s	Measured: ASME1321

Figure 13: Al12Si characteristics

4.5 Existing machines

For the different processes, we have been working in, we have used different machines that have to be said because without them is totally impossible to be able to cast. These are the machines we have used:

MACHINES FOR PROCESSES		
NAME	**REFERANCE CODE**	**PROCEDURE**
Naberthem	K4/10	Melting metal
Heracus	K750/2	Pre-heating for die casting mold
Instron	4204	Tensile testing (Loadcells; 50 kN, 5 kN, 500 N)

Table 5: Machines for casting processes

These three machines are crucial for being able to cast, due the fact that we don't want to give a lot of technical information, you can find out the specific details of every machine in the appendix of this report.

4.6 Technical requirements

The Requirements Document is a contract between the client, the supervisors and the project team. It is a document which presents the list of functionalities and performances that the client demands and the team is engaged with. This document must be signed by both parts. After finishing research on foundry processes we began brainstorming about the deliverables and the possible design for the parts we were going to cast.

The requirements were written with the help of our technical supervisors who gave us a good starting point. Due the fact that two of the three supervisors were also our clients, when we had meetings with the technical supervisors we were able also to discuss about the requirements of the project and their specific requirements. This led to a completed requirements document, detailing the functionalities and performances to be followed by the foundry process project.

The full requirements document can be found in the appendix.

4.7 Technical development process

We started with the development of the process reading about technical things for the foundry process, starting to set all the different deliverables and the possible designs for the different parts we were going to cast. For that, we had a brainstorm to talk about the possible designs and finally we got the final design that you can check out in the 4.8 point of this report.

Due the fact that we don't want to put a lot of information in the main report, we have explained the development of the designs in the appendix that it is attached at the end of this report.

4.7.1 Calculations

About the calculations, we have calculated all the parameters for the three processes, those are in the handbook because it is important for the students to know why the feeders are that big or how many time the aluminium takes to get solidify again. The handbooks are attached at the appendix and also the calculations alone, we preferred to keep it like this because there are a lot of technical results that are not showing a lot of interesting things, it is just something important to calculate for being able to design the part.

4.8 Final design

We are going to explain the final design of the different parts we have casted splitting them between the three different processes. As we have said in the last point, you can check out the development of the design in the appendix.

4.8.1 Sand casting

We know this part as a goodie, it is going to be cast is a bottle opener with the ENIT letters and also with a bear footprint on it because the bear is the animal of the university. The goodie looks like this:

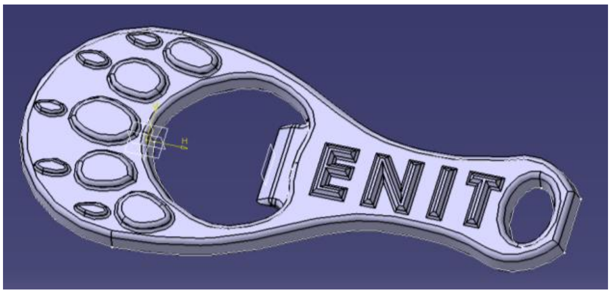


Figure 14: Sand casting part

For casting we have also designed the feeders and a total of six goodies together for making it easier for the students:

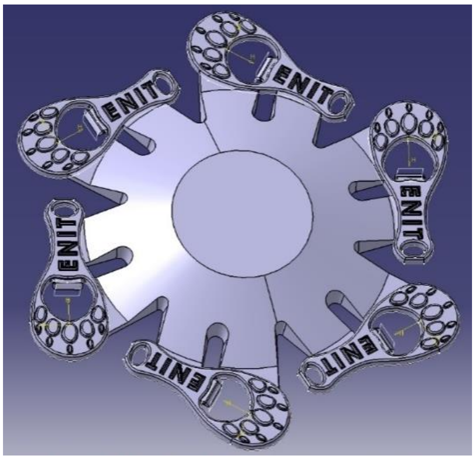


Figure 15: Sand casting part with feeders

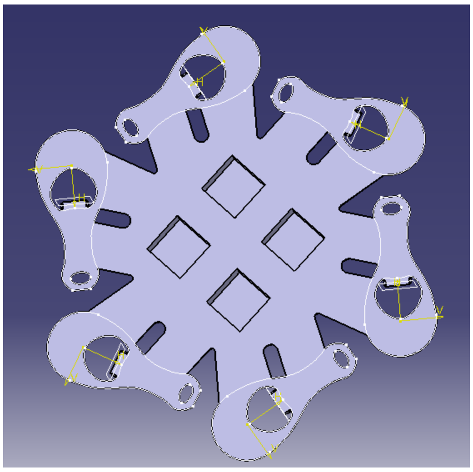


Figure 16: Sand casting part with feeders, bottom view

Also, we have designed three tensile test parts with their feeders to be casted with sand mold casting, this is the design of that part:

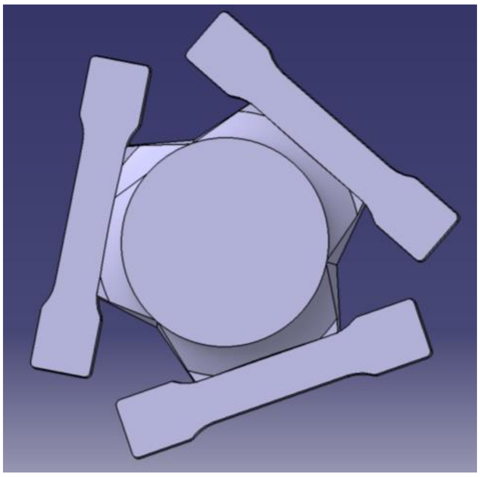


Figure 17: Sand casting process tensile test parts

4.8.2 Lost wax casting

For the lost wax process, we have designed a part that has a difficult shape to show that with this process you can cast parts that are impossible to cast with other casting processes. Our clients told us to design something for the university so we decided to use a design already created because it has the perfect shape and is very meaningful for the university, due the fact that it is saying ENIT in one face of the part and INPT in the other, which is the name of the "National Polytechnic Institute of Toulouse" the main university where the ENIT is attached.

In the following two pictures, you can find out the final design of the part for lost wax process:

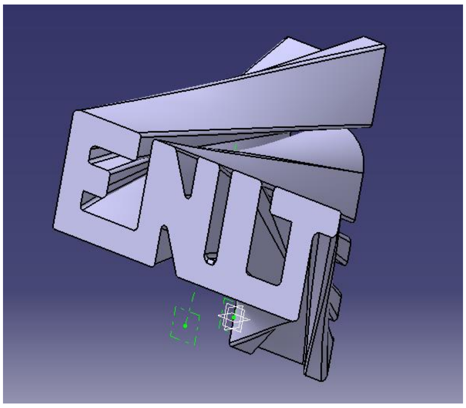


Figure 18: Lost wax part (ENIT face)

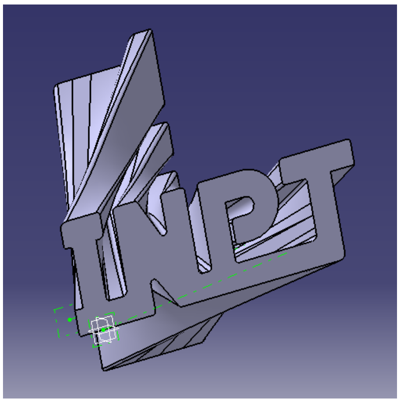


Figure 19: Lost wax part (INPT face)

4.8.3 Die casting mold

The die casting process is the one we haven't finish, because the problems about the calculations and the time they took to accomplish them but finally we got the correct results and we were able to design the die casting mold with the three tensile test parts inside. The mold looks like this:

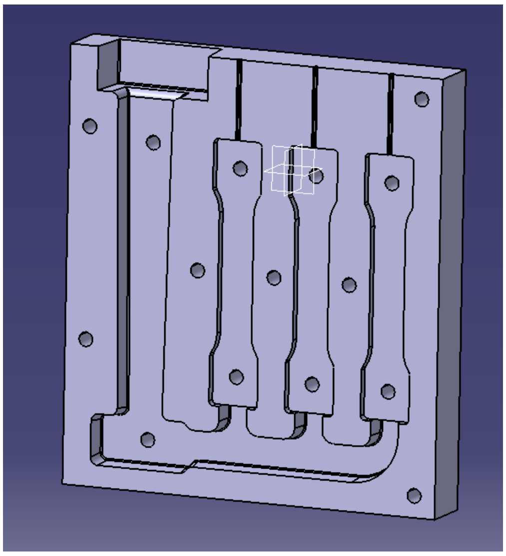


Figure 20: Die casting mold

5. Management

This chapter gives an overview of all the work done by the team on the management side of the project. This report has explained the technical aspects of the project, what has been done and what were the goals achieved. All these work, could not had been properly completed without management. This section will show how the project was structured, planned and monitored in order to develop the work as well as possible.

5.1 Work Breakdown Structure and workload

The Work Breakdown Structure (WBS) is a chart in which the main tasks of the project are illustrated to represent their relationship to each other and to the project as a whole. According to that is a basic project management technique to help identify and organize the project with a hierarchical structure.

The WBS has been modified as the project has been defined; resulting in several versions that you can find in the appendix of this report as also the comparison between the updated version and the old one.

The main objective of WBS is to define the different tasks in order to make clear which are the goals of the project. The diagram starts with a single box that refers to the entire project. The project is then divided into related components, always putting together the components that are similar. In practice, the upper components are the deliverables and the lower level elements are the activities that create the deliverables.

Our WBS shows in a clear way all the different tasks that had to be executed to accomplish the project objectives. The structure aides to organize and define the overall scope of the project. The WBS is composed of four main deliverables and their associated tasks to accomplish the main deliverable, those are:

- CAD files
- Physical parts
- Handbooks
- Documents

We preferred to organize it this way because we have a lot of similar deliverables but from different foundry processes, with this type of organisation, makes the WBS simpler than creating branches from every process. Each of the boxes were labelled with a specific code (A - activity, D - deliverable) which also have been used for MS Project.

Due to the technical problems that were explained earlier in this report, we decided to delete those deliverables from the WBS because they were not something to deliver to our clients anymore.

In the following figures, you can find out our WBS:

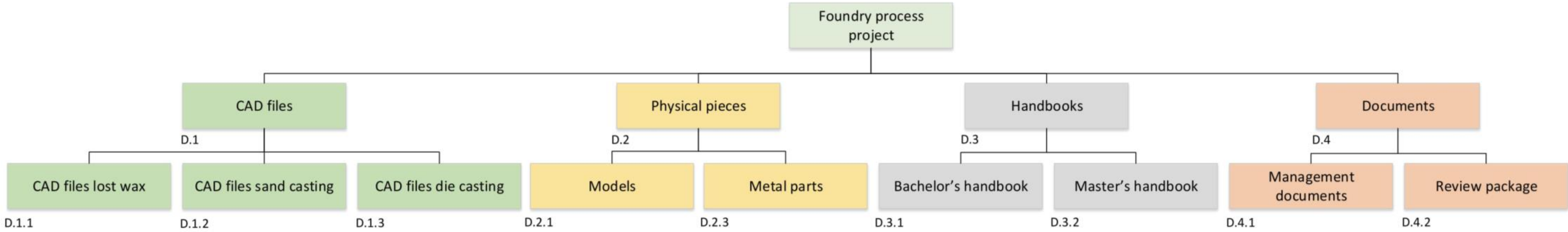


Figure 21: Diagram of the main branches of the WBS

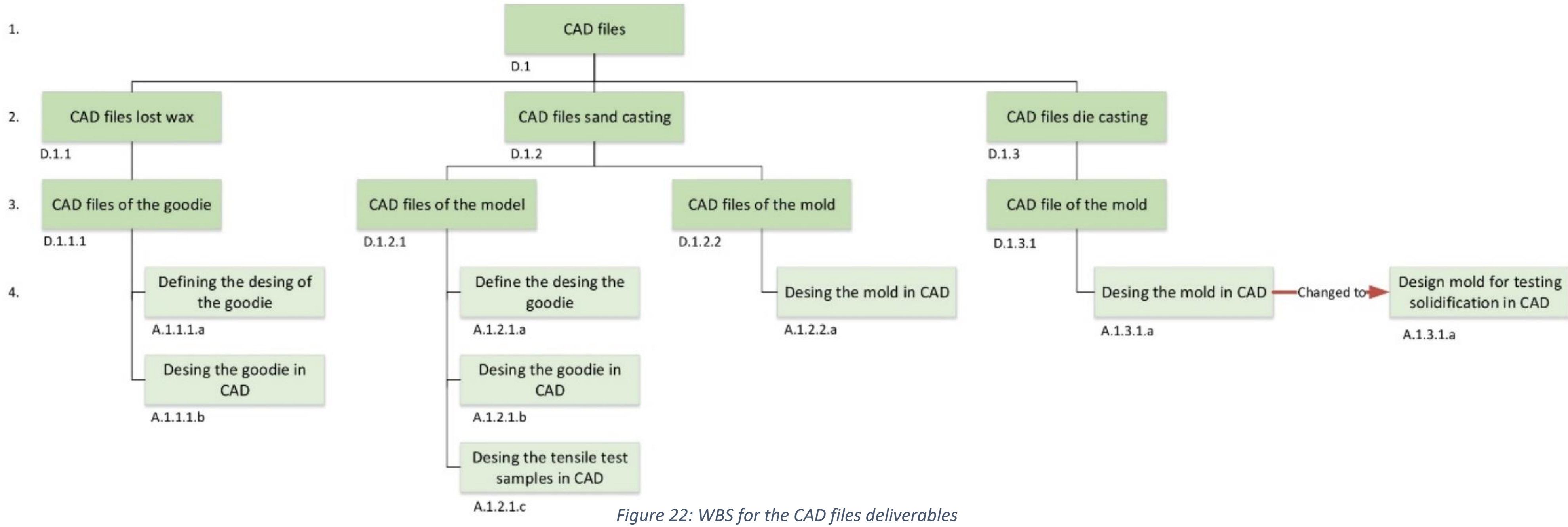


Figure 22: WBS for the CAD files deliverables

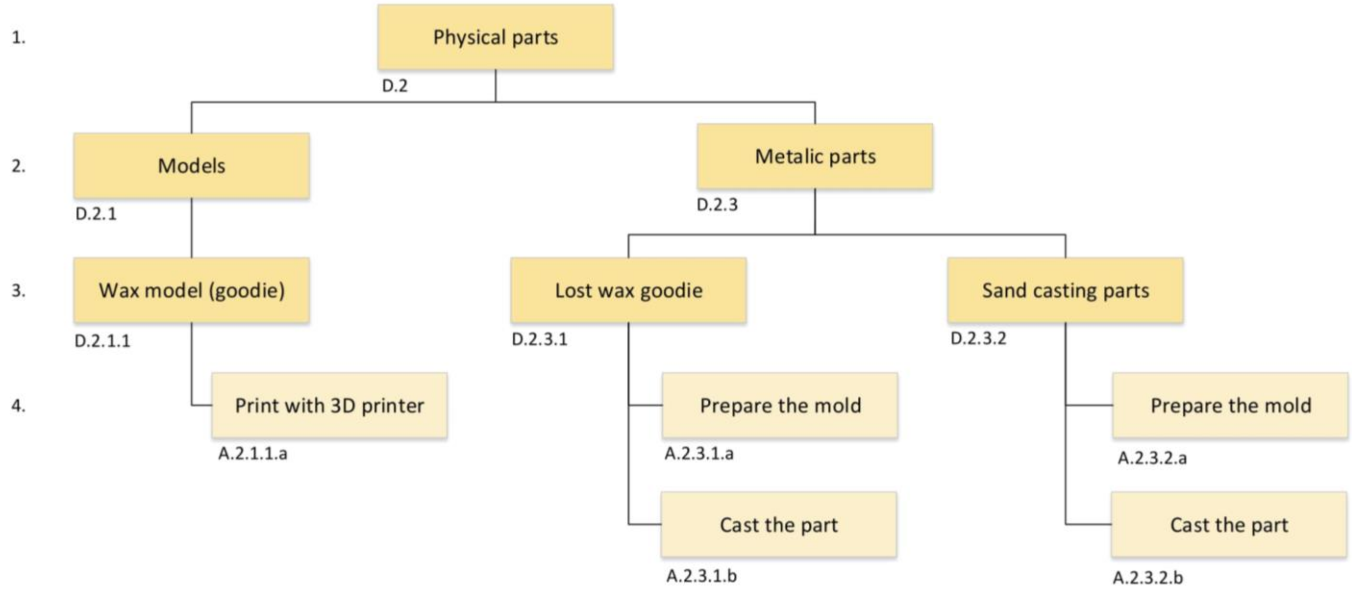


Figure 23: WBS for the physical parts deliverables

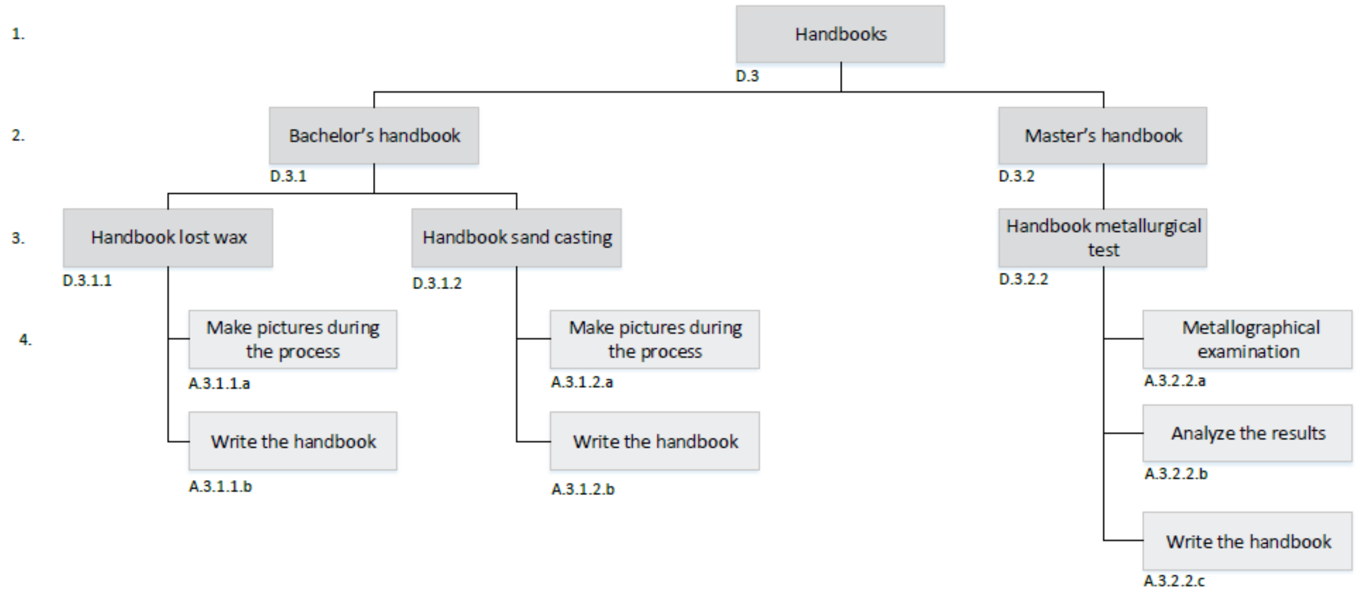


Figure 24: WBS for the handbooks deliverables

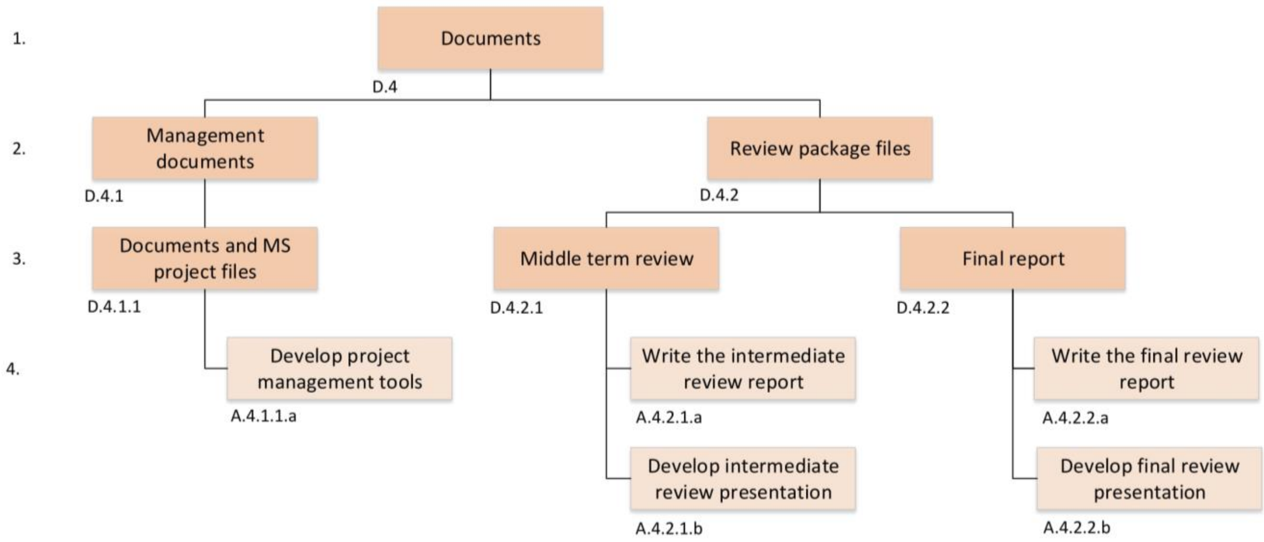


Figure 25: WBS for the documents deliverables

5.3 Monitoring

5.3.1 Workload

The number of hours available for work on the project were settled at the beginning when the project was planned. For doing that the weeks of duration of the EPS was taken in count, and the daily work hours were estimated between seven and eight.

During the project, it has been verified how this estimate was not correct. Not every week were available for work on the project in order there was some holidays at the EPS course.

The work hours per day forecasted, wasn't accurate enough in order their lectures during the EPS program that doesn't allow to spend all the working day on the development of the project.

According the work realized during the project and taking in count the holidays and the lectures, the working hours are described again.

Totals weeks of the project	17
Total "ferié" days	18
Total lectures hours	112
Total events hours	39
Real work hours per person	251
Real work hours	1255
Estimation of works hours	1960

Forecast miscalculation	705

Table 6:Distribution of hours among the course of EPS.

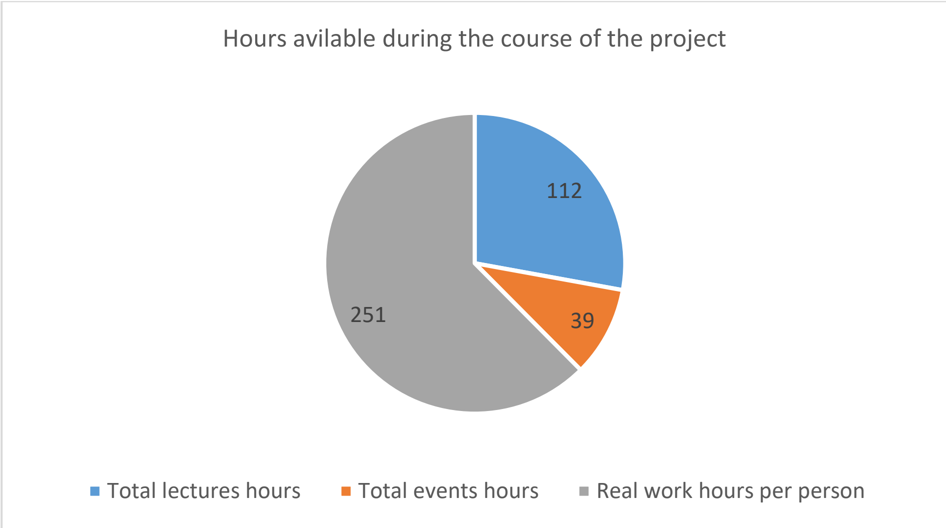


Chart 1: Distribution of hours among the course of EPS.

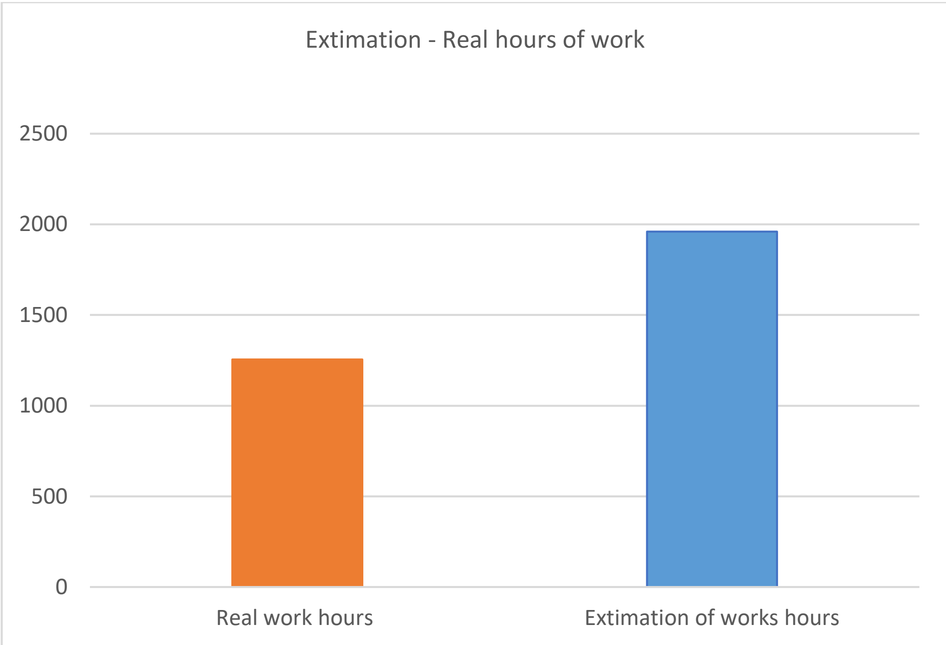


Chart 2: Estimation and real hours of work

The time dedicated to different tasks and deliverables also has changed per the time forecasted at the beginning. Obviously, the time dedicated for some deliverables that are not going to be deliver, due to problems arising during the project, is zero.

A.1.2.1. b	Design the goodie in CAD
D.2.1.2	Polyurethane model
A.2.1.2. a	Manufacture the model
D.2.2	**Melds**
D.2.2.1	Die casting mold
A.2.2.1. a	Buy/make the die casting mold
A.2.3.3. a	Cast the piece
A.3.1.3. a	Make the pictures during the process
A.3.1.3. b	Write the handbook
A.3.2.1. a	Execute tensile test
A.3.2.1. b	Analyse the results
A.3.2.1.c	Write the handbook

Table 7: Task and deliverables settled down to cero in the workload.

The duration of the rest of activities also changed according to the predefined one. Some of them take less time than the forecasted, other more, and other couldn´t took more time, due the installations needed weren´t available. The workload redefined is the next one.

The activities of the CAD files have a different duration that the predicted one, the time dedicated to this deliverables group, is almost the half of the time predicted, all the time has been reduced. Largely due we didn´t had to design the lost was goodie, because we used a design issued by the supervisors.

WBS	Task name	Workload [h]	Estimated workload [h]
D.1	**CAD files**	**170**	**300**
D.1.1	**CAD files the lost wax**	**10**	**100**
D.1.1.1	CAD files for the goodie	10	100
A.1.1.1.a	Defining the desing of the goodie	10	20
A.1.1.1.b	Desing the goodie in CAD	0	80
D.1.2	**CAD files sand casting**	**110**	**150**
D.1.2.1	CAD files for the model	80	110
A.1.2.1.a	Define the desing of the goodie	20	20
A.1.2.1.b	Desing the goodie in CAD	50	80
A.1.2.1.c	Desing the test pieces in CAD	10	10
A.1.2.1.d	Design of the plate in CAD		
D.1.2.2	CAD files of the mold in CAD	30	40
A.1.2.2.a	A desing of the mold in CAD	30	40
D.1.3	**CAD files die casting**	**50**	**50**
D.1.3.1	CAD files of the mold	50	50
A.1.3.1.a	Desing the mold in CAD	50	50

Table 8:Estimated workload and real workload for Cad files deliverables.

The estimated workload for the physical parts has also decreased compared to the expected, since we did not have to manufacture the model in polyurethane we printed the model with the 3d printer. Although it would have been better to spend more time testing the casting process, technical problems did not allow us to do so.

We do not deliver the casting mold and, consequently, we do not spend time in its manufacture or purchase.

WBS	Task name	Workload [h]	Estimated workload [h]
D.2	**Physical parts**	**140**	**350**
D.2.1	**Models**	**10**	**150**
D.2.1.1	Wax model (Goodie)	10	60
A.2.1.1.a	Print with 3D printer	10	60
D.2.1.2	Poliurethane model	0	90
A.2.1.2.a	Manufacture the model	0	90
D.2.2	**Molds**	**0**	**30**
D.2.2.1	Die casting mold	0	30
A.2.2.1.a	Buy/make the die casting mold	0	30
D.2.3	**Metalic pieces**	**130**	**170**
D.2.3.1	Lost wax goodie	70	80
A.2.3.1.a	Preapare the mold	50	60
A.2.3.1.b	Cast the piece	20	20
D.2.3.2	Sand casting pieces	60	60
A.2.3.2.a	Prepare the mold	40	40
A.2.3.2.b	Cast the piece	20	20
D.2.3.3	Die casting pieces	0	30
A.2.3.3.a	Cast the piece	0	30

Table 9: Estimated workload and real workload for physical parts deliverables.

The time provided for the development of the manuals was also overvalued. We did not deliver the manual for the mold casting process and for the tensile test, because we could not develop it in a practical way.

The time required to write the manuals was also less than that expected for the start of the project. Describing the lost wax process was simpler than expected.

WBS	Task name	Workload [h]	Estimated workload [h]
D.3	**Handbook**	**160**	**430**
D.3.1	**Bacherlor´s handbook**	**80**	**210**
D.3.1.1	Handbook lost wax	30	70
A.3.1.1.a	Make pictures during the process	10	10
A.3.1.1.b	Write the handbook	20	60
D.3.1.2	Handbook sand casting	50	80
A.3.1.2.a	Make the pictures during the process	10	10
A.3.1.2.b	Write the handbook	40	70
D.3.1.3	Handbook die casting	0	60
A.3.1.3.a	Make the pictures during the process	0	10
A.3.1.3.b	Write the handbook	0	50
D.3.2	**Master handbook**	**80**	**220**
D.3.2.1	Handbook tensile test	0	110
A.3.2.1.a	Execute tensile test	0	20
A.3.2.1.b	Analyze the results	0	20
A.3.2.1.c	Write the handbook	0	70
D.3.2.2	Handbook metallurgical test	80	110
A.3.2.2.a	Execute metallurgical test	20	20
A.3.2.2.b	Analyze the results	20	20
A.3.2.2.c	Write the handbook	40	70

Table 10: Estimated workload and real workload for Handbooks deliverables.

The documents time has been also reduced but not in the same way it was at the others. Writing the report has taken almost the same time as it was predicted. But the Project management activities has been reduced notably, we spent less time than expected on that.

WBS	Task name	Workload [h]	Estimated workload [h]
D.4	**Documents**	**785**	**880**
D.4.1	**Management document**	**500**	**600**
D.4.1.1	Documents and MS file	500	600
A.4.1.1.a	Defining the project	400	400
A.4.1.1.b	Project management activities	100	200
D.4.2	**Review package files**	**285**	**280**
D.4.2.1	Middle term review	100	100
A.4.2.1.a	Write the intermediate report	80	80
A.4.2.1.b	Develop intermediate review presentation	20	20
D.4.2.2	Final report	185	180
A.4.2.2.a	Write the final report	100	140
A.4.2.2.b	Develop final review presentation	85	40

Table 11: Estimated workload and real workload for documents deliverables

5.3.2 Milestones

The milestones were stablished to have a control of the accomplishment of the different stages of the project.

The milestones defined at the beginning of the project got predetermined date to be accomplished. It is possible by recording when the stage is accomplished know how the development of the project goes.

It is possible checking the milestones chart what is the difference between the described date at the beginning of the project and the final one.

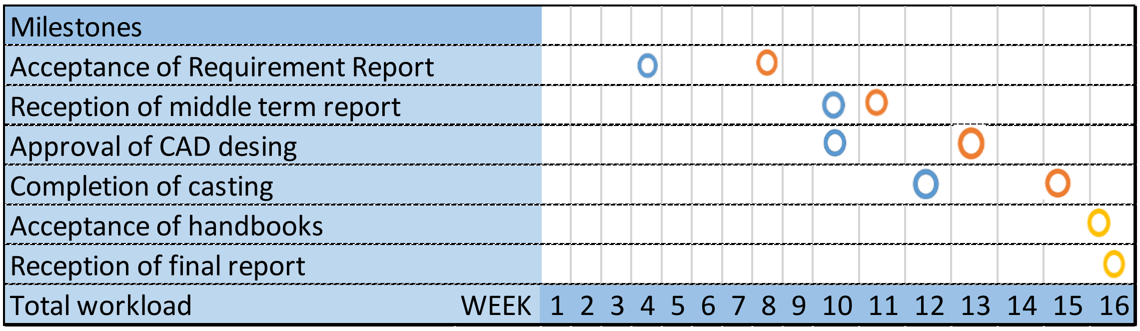


Chart 3: Milestones chart.

; the milestone date settled at the beginning of the project.

; the date when the milestones are reached.

; the settled date at the beginning and the real one are the same.

It is notable the difference in the case of the requirements document that takes a long time to be accepted.

The way of working at the lab with the casting processes made that the CAD design approvals and the completion of the casting were delayed, due after each casting the model and the metrology was improved.

5.4 Costs

A budget is a quantitative expression of a plan for a defined period. Financial assessment helps to determine the total cost of the project. This allows you to calculate project costs.

5.4.1 Calculation of salaries for specialists

To roughly work out the cost of the project, we used at the number of hours done by each person and salary. The table presents the project group and the project supervisors. This an estimated salary based on the information found in the Internet.

Name	Number of hours	Salary (for 6h day)	Total cost
Oriol FONELLOSA	245	200€ / 6 hours = 33,33 €/h	8166 €
Justyna KĘDZIAK	245	200€ / 6 hours = 33,33 €/h	8166 €
David SAEZ DIEZ	245	200€ / 6 hours = 33,33 €/h	8166 €
Marvin STRUβ	245	200€ / 6 hours = 33,33 €/h	8166 €
Semih YÜKSEL	245	200€ / 6 hours = 33,33 €/h	8166 €
Yannick BALCAEN	20	800€ / 6 hours = 133,3 €/h	2666 €
Francois GRIZET	18	800€ / 6 hours = 133,3 €/h	2400 €
Guillaume MAZENC	15	800€ / 6 hours = 133,3 €/h	2000 €
Philippe FILLATREAU	10	800€ / 6 hours = 133,3 €/h	1333 €
		Total cost	***49 233 €***

Table 12: Salary of the members and total cost

About the cost of the equipment we can say:

Equipment	Total Cost	
Electricity used by ovens and 3D printers	29€	
Filament	30€	
Aluminium	Recycled	
Sand	80% is recycled, a new 50 kg box of sand is 35€	
	Total cost	***94 €***

Table 13: Equipment cost

The data used for the calculations are derived from the information provided on the devices, web pages and data obtained from laboratory staff. The table shows the main costs.

5.5 Summary

This chapter has explained the steps we took to plan our project and compared it against what happened during the project. Whilst there were a few delays, the project has nonetheless been completed on time, and we have met all of the deliverables, at least all the deliverables included in the plan B. The most useful tool was effectively monitoring the project. By being 100% busy all of the time we ensured that there was a minimum amount of delay.

6. Pedagogy and practical class structure

6.1 Foundry processes

We have discussed with our clients about the pedagogy and the way to split the practical class, according with them we have split the bachelor's students practical class in three days and this is the structure:

Day 1. For the work of the first day you will need about three hours. In the beginning, all twelve students prepare the mold for the lost wax process. After they split in three groups of four students. Every group is preparing one mold. One group makes the mold for the three testing parts and the other two groups prepare a mold to for six bottle openers.

Day 2. The second day is divided up on two sessions of one hour. In the morning, they should turn on two furnaces. One to heat the lost wax mold and evaporate the wax and the second one to melt the aluminium you are going to use for the casting process.

In the afternoon, there is another short session. Here you will perform the two casting processes.

Day 3. For the last day, we also planned three hours. The students must destroy the four molds to get the casted production. After they will cut out the parts and grind them. If they finished the work, we have planned a discussion for between the students. They should talk about their experience with foundry processes, their mistakes and the things you have done well for 20-30 minutes.

Finally, they can deliver the lost wax goodie and the parts for testing to their laboratory teacher, take their bottle opener and try it at the Foyer (which is the social room of the university) or somewhere else.

6.2 Metallographic tests

The Master handbook consists of just one process. There is a metallographic examination for tensile test part casted during the bachelor's practical class. The Master Handbook is designed for master students and it will take a time of about two hours. With the metallurgical test process, students will prepare a sample for metallographic examination and analyse the results.

We have 1 day for all stages of metallographic examination.

Day 1: For the whole process students will need about two hours. In the beginning, all master students cut the sample in 2 directions. After they obtain the cut parts, students mold them. After the molding process is complete, the molded parts will be grinded. After each stage of the grinding process has been successfully completed, polishing and etching processes will be performed. Then the sample preparation process is completed and the prepared sample can be examined under the microscope.

Finally, the students will see images of the sample while examining the samples at the microscope and they will be able to analyse the images with their teacher.

7. Final Assessment of the Project

At this point, all the work done by the group, in technical and management context, has been explained. The aim of this chapter is to review all the progress the team has made during the development of the project by going through our goals and what we have learnt by doing this project. We have not only looked at what has been carried out by the team but also have considered what we could improve in future projects. Finally, we are going to explain the next steps to achieve those deliverables that we have not delivered.

7.1 Achievement of the objectives

The best way to check if the objectives of the project were achieved is by going through the deliverables that were established by the team with the client.

This project had four main deliverables: Handbooks, CAD files, Physical parts and Documents. All of these deliverables were completed, according to the B plan:

Deliverables	Status
Handbooks	✓
D.3.1 Bachelor's handbook (About lost wax and sand casting methods)	✓
D.3.2 Master's handbook (About metallurgical test)	✓
CAD files	✓
D.1.1.1 CAD files of the goodie lost wax	✓
D.1.2.1 CAD files of the models for sand casting	✓
D.1.2.2 CAD files of the mold for casting	✓
D.1.3.1 CAD file of the mold for die casting	✓
Physical parts	✓
D.2.1.1 Lost wax goodie in wax	✓
D.2.1.2 Printed model sand casting goodie and three testing part in 3D printer	✓
D.2.3.1 Lost wax goodie casted in aluminium	✓
D.2.3.2 Sand casting parts casted in aluminium	✓
Documents	✓
D.4.1.1 MS project files	✓
D.4.2.1 Middle term report	✓
D.4.2.2 Final report	✓

Table 14: Status of the deliverables

7.2 What have we learnt

This project has been a great experience for us, the project work was interesting and we worked well in a team. From this semester, we will take away some stronger team skills- none of us had worked on such a long project with such a big team, because we were used to work in our universities in teams not bigger than three people. We have also gotten better at time management and organisation. We learnt that is important to properly plan your work and time, and that having good organisation brings better results.

One of the fields in which we have made a good improvement was in understanding the technical things about our project and the importance of setting up meetings with people who can help us. Is important to organize those meeting sending before the meeting an agenda about what we are going to discuss and after the meeting a report about what has been discussed and the following actions the project is going to take. This was a challenging factor, and a mistake we made coming up to the intermediate review, because we were not able to organize properly the meetings due that was difficult for us to understand the technical issues of our project. Finally, we started to think positively and we those understanding problems disappeared, it was too late for the intermediate report but not for this final report.

From this we learnt to plan well ahead for the final review, making things simpler and clear and also having a meeting with our technical supervisors and management supervisor every week.

We have made improvements in how to run a project using management, and also made improvements on the technical side of the project, learning the importance of reaching a clear agreement on the requirements with the clients to avoid future problems. In this field, we have also improved our technical skills by learning a new tool CATIA V5 which we can use to make CAD drawings, some of us we knew about SolidWorks which is a similar program but it is a really good ability to know about both software's. We have learnt about 3D printers, how they work and the software that is necessary to work with them, in the management point of view we have achieved a lot of knowledge especially working with MS project.

7.3 What we would do better

Even though we have achieved all our goals by the end of the project, at least our objectives in the plan B, there is more we could do to improve the result achieving the plan A. First of all, we run out of time to achieve the plan A, meaning that there are four deliverables that are not going to be done for different reasons that have been explained during this report. We really think we have done a good job because we have worked in two different process, one of them which is the lost wax that had never been used in the ENIT and we have obtained good results in the process of printing in wax, creating a mold and melting the wax to finally cast and get a part.

We know that we haven't achieved the die casting process but we are pleased because our supervisors say that we have done a really good job and we have to be proud of it, after all we knew that probably we will have some time problems and with all the different problems about the machines we had, which there were not our fault, we have done a good project and obtained respectable results.

7.4 Next steps

Even though we have achieved all our goals by the end of the project, there is more we could do to improve the result because we have achieved just the B plan, otherwise we will like to make clear the next steps to accomplish all the deliverable including those in the A plan. For the plan A should be done the next deliverables:

- Die casting mold (D.2.2.1)
- Tensile tests (D.3.2.1)

For the die casting mold we have calculated all the dimensions, which are in the appendix and also, we are bringing the CAD file of the actual die casting mold, the next steps for this process are:

1. Make sure that the real time of solidification is the same or near to that one calculated.
2. Once the calculations are verified, send the design to the company that is going to manufacture it.
3. Cast with the die casting mold.
4. Obtain three tensile test parts.

For the tensile tests, the next steps to follow basically are to repair the machine of the laboratory, because it has never worked but as soon it is repaired, it will be possible to do the tensile tests and obtain results.

8. Conclusions

This project was focussed on the design of two handbooks for the students of the ENIT university in Tarbes, France. These two handbooks have been developed by a team of five people working together during a semester in a program known as EPS. During our project, we have achieved our goal with the plan B and because of that we are proud of the work done.

To achieve this goal, we worked hard on researching all aspects of the three different foundry process, because we started from zero knowledge about the subject. With all this information, we could then define the specific technical requirements the design had to accomplish. At first, the project was a little time consuming because all of the different new knowledge was given to us by the supervisors and also because of the fact that the processes are a little bit complicate to understand. Secondly, we wanted to make clear and order all tasks in one list to make sure we were achieving all our objectives, when we had this done it was the moment to start designing with CATIA and casting in the laboratory.

At this point, a complete idea for the design of the different parts for casting were completed, it is true that we have achieved just the B plan, and we are proud of that, but we know that the project has to achieve also the A plan to be totally finish and we have left all the tools necessary to finish it as soon as the broken machines are repaired. We wanted to make clear all the next steps for the following team that is going to continue with this project. We think that without the problems with the broken machines we will have finish the whole project, including the A plan, but due the problems with the equipment that we have explain during this report, was impossible to achieve.

Sideways from what only concerns the foundry process project, the team members have gained a lot of experience in several fields which will be very useful in their professional lives. We have learnt how to run and manage a project, how to work in teams, collaborate with clients and finally how to communicate in an appropriate way despite is with our team members, clients or supervisors.

To summarise a little bit, we will like to say that we have enjoyed a lot this project and also the experience of working together as a team, at the ENIT there are really good facilities and it has been a pleasure for us being doing a project here.

Finally, we think that the EPS semester is a great opportunity to get a lot of experience in living by ourselves in a foreign country, learning about the culture and language of France whilst improving our technical and management abilities. We really recommend this experience.

9. List of figures

10. List of tables

11. List of charts

12. References

Sand producer

http://www.kbo-gmbh.de/

Metallographic examination

https://www.muhendisbeyinler.net/metalografik-muayene-nedir-ve-nasil-yapilir/

About casting

http://www.teknikyaz.com/2015/05/dokum-nedir.html

http://www.aktuelarkeoloji.com.tr/kayip-mum-teknigiyle-dokum

http://metalurjistman.blogspot.fr/2012/01/kum-kaliba-dokum.html

ASM HANDBOOK Volume 15 Casting

Handbook of materials for product design

http://www.custompartnet.com/wu/SandCasting

http://www.afsinc.org/content.cfm?ItemNumber=6898

http://www.mibot.com/foundry/molds.php

About metalic alloys

https://www.dynacast.com/413

http://www.matweb.com/search/datasheet.aspx?matguid=641c7123204a4c6bb81190f8685cf60d&ckck=1

Handbook of materials for product design, Charles A. Harper

About model calculations

https://en.wikipedia.org/wiki/Chvorinov%27s_rule

http://www.themetalcasting.com/solidification-time-rate.html

http://docplayer.org/27989597-Viskositaetsmessungen-an-binaeren-legierungen-des-aluminiums-mit-silizium-zink-kupfer-und-magnesium.html

http://rules.dnvgl.com/docs/pdf/gl/maritimerules/gl_vi-1-1_d.pdf

http://www.urs-brandenberger.de/down1.pdf

EJERCICIOS RESUELTOS DE TECNOLOGIA MECANICA, by de Jesús Peláez Vara , Esteban García Maté , Francisco Javier Gómez Gil.

About machines

http://www.nabertherm.com/produkte/details/en/labor_schmelzoefen, access 02.06.2017
http://labotest.se/wp-content/uploads/2015/12/High_Temp_Furnaces_E_0302.pdf, access 02.06.2017
http://www.struers.com/media/Library/Instruction_Manuals/PlanoPol.pdf?dmc=1&ts=20170403T1006172614

http://www.metallographie-presi.de/cms/

13. Appendix

Appendix 1

Requirement document

In the first section of the appendix, we attached our requirement documents. They got signed by our technical supervisors Mr. Grizet, Mr. Balcaen, Mr. Mazenc, our management supervisor Mr. Fillatreau, and our clients, Mr. Balcaen and Mr. Mazenc again. Also, all the team members of the project group JOSMD singed the requirement documents at the 25.04.2017.

Besides some theoretical knowledge about the processes we are going to use, we explained all our deliverables, exclusions and project planning.

European Project Semester

Foundry process

JOSMD EPS FOUNDRY

Requirement document

Category	Name	Signature
Technical Supervisors	GRIZET Francois	
	BALCAEN Yannick	
	MAZENC Guillaume	
Management Supervisor	FILLATREAU Philippe	25/04/2017
Clients	BALCAEN Yannick MAZENC Guillaume	
Team members	KĘDZIAK Justyna	J. Kędziak
	FONELLOSA Oriol	
	STRUSS Marvin	
	SAEZ DIEZ David	
	YÜKSEL Semih	

Tarbes, 25/04/2017

v1.5

Content

1. Context

The project is developed around the European Project Semester program, according the Erasmus mobility program, for European Students. The aim of this program is to promote the teamwork of international European students. This project will be realised at the École Nationale d'Ingénieurs de Tarbes. This project starts with the proposal by the teachers of developing learning guides about foundry process.

2. Objectives

Our main objective in the foundry process project is to create two guides, one for bachelor students and another one for master students. In the first case, we must create a practical guide of four hours, where bachelor students are going to try three different types of casting; lost wax, sand casting and die casting. In the second case master students are going to do some quality tests with standardized pieces, this practical guide is going to last for eight hours.

In the bachelor guide as we have said, are going to do three different type of casting, in the first one they are going to use the lost wax method and they are going to cast a goodie that they could keep for their self. In the second method, students are going to cast sand casting with the aim of casting three regulated pieces for testing quality and, they are going to obtain a goodie with the same mold. Finally, in the third method, which is die casting, students are going to cast three pieces that master students are going to use for quality tests as they have done in sand casting, these pieces are standardized, so they are always the same.

For obtaining these two guides we will have to try all the steps in the laboratory, in the same situation as the students.

3. Clients/Stakeholders

3.1. Clients:

Yannick BALCAEN Materials Science	**Guillaume MAZENC** Manufacturing Processes

3.2. Technical Supervisors

Francois GRIZET Computer Assisted Design	**Yannick BALCAEN** Materials Science	**Guillaume MAZENC** Manufacturing Processes

3.3. Management Supervisors

Philippe FILLATREAU
Project Management

3.4. Team members:

Justyna KĘDZIAK
Management and Production Engineering
Lodz University of Technology

Oriol FONELLOSA
Mechanical engineering
Universitat Politècnica de Catalunya

Marvin STRUSS
Industrial engineering
Ostfalia University of Applied Science

David SAEZ DIEZ
Management engineering
Universidad de Burgos

Semih YÜKSEL
Metallurgical and Materials Engineering
Marmara University

4. Background

4.1. Foundry and Casting

Foundry is the general name of factories that work with casting. Casting is one of the most used production methods in the world. Firstly, the metal is melted and poured into the mold. Then molten metal is expected to take shape inside the mold and solidify after it has been shaped. After the solidification is completed, the formed cast piece is removed from the mold in various ways. The most commonly used casting materials are aluminium and cast iron.

COUNTRY	TOTAL NUMBER OF FOUNDRY
China	12000
India	4500
U.S.A	2620
Russia	1900
Mexican	1787
Japan	1713

Table 1 *- Total foundry numbers of countries*
http://www.metalurji.org.tr/dergi/dergi141/d141_1824.pdf

Casting process has existed for thousands of years and it has been used especially in ancient times to produce precious jewellery, weapons for hunting and various tools. Nowadays, casting is used in every sector, from toy production to heavy industrial.

Casting methods are divided into types according to the types of mold. These types are:

- Expendable mold,
- Permanent mold,
- Others.

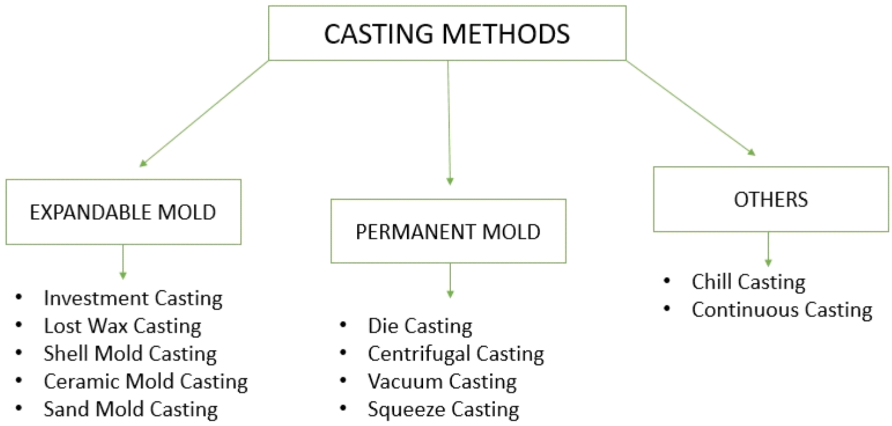


Figure 1 - *Casting methods*

Three types of casting method will be used in this project:

- Lost wax casting,
- Sand casting,
- Die casting.

4.1.1. Sand casting

Sand mold casting is one of the most used and oldest types of casting method. There are six steps in this process:

- Place a pattern in sand to create a mold.
- Incorporate the pattern and sand in a gating system.
- Remove the pattern.
- Fill the mold cavity with molten metal.
- Allow the metal to cool.
- Break away the sand mold and remove the casting.

7

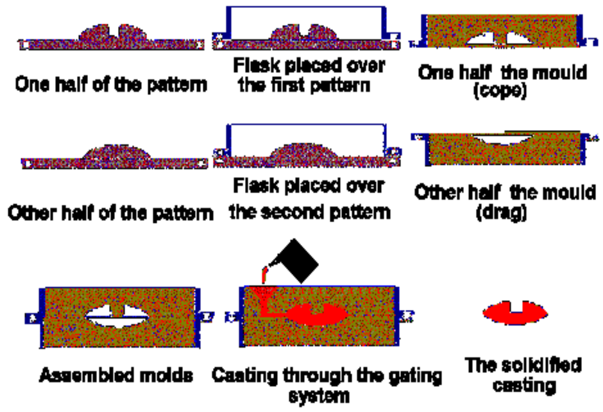


Figure 2- *Steps of the Sand Mold Casting*
https://upload.wikimedia.org/wikipedia/commons/2/2b/Haandform-e.png

4.1.2. Lost wax casting

Lost-wax process, is a method of metal casting in which a molten metal is poured into a mold that has been created by means of a wax model. Once the mold is made, the wax model is melted and drained away. A hollow core can be effected by the introduction of a heat-proof core that prevents the molten metal from totally filling the mold. The lost-wax method dates from the 3rd millennium BC and has sustained few changes since then. There are five steps in this process:

- Wax shape is designed.
- The mold is produced with the wax shape.
- The mold is preheated in a furnace to melt the wax and molten metal is poured into the resulting cavity.
- Allow the cast metal to solidify and allow it to cool.
- After molten metal has cooled, the mold can be broken and the casting removed.

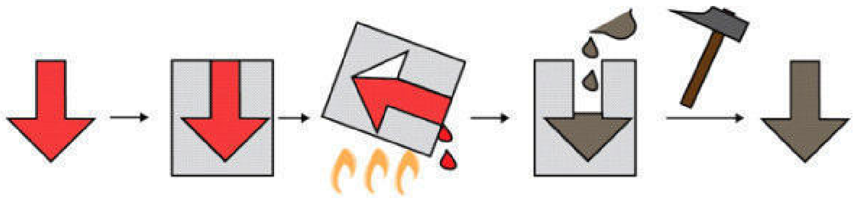


Figure 3- *Steps of the Lost Wax Casting*
http://static.projects.iq.harvard.edu/files/styles/os_files_large/public/sorotoolkit/files/cda-lostwax-1.png?m=1413397906&itok=KTrfaX6o

4.1.3. Die casting

Die casting is a metal casting process that is characterized by forcing molten metal into a mold cavity. Casting mold is usually made of hard tool steel. Generally, this method is used for casting specifically zinc, copper, aluminium, magnesium, lead, pewter and tin-based alloys. Depending on the type of metal being cast, a hot- or cold-chamber machine is used. There are four steps in this process:

- Design the steel mold and manufacture it.
- Pre-heat the mold and use lubricant to prevent the adhesion of the molten metal to the mold.
- Metal is poured into the resulting cavity and allow the cast metal to solidify and to cool.
- Open the mold and remove the casting.

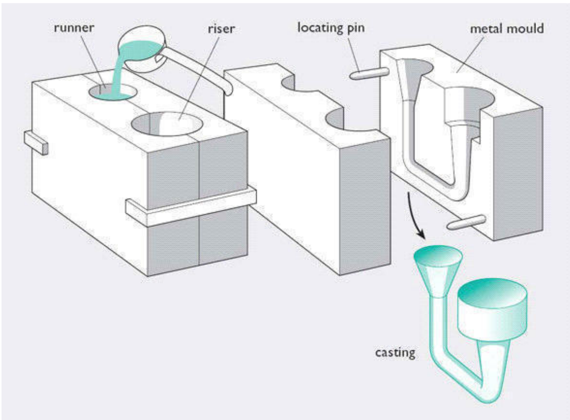


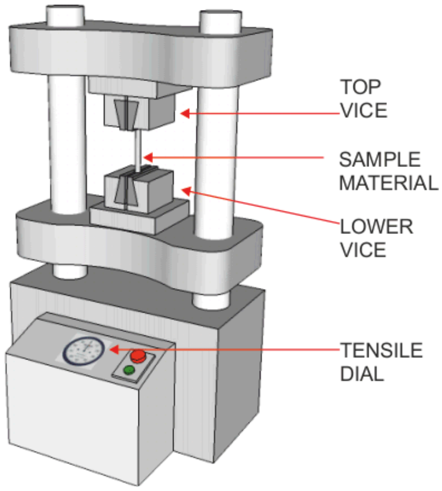
Figure 4- *Steps of the Die Casting*
http://www.learneasy.info/MDME/MEMmods/MEM30007A/processing/processing_files/T173_2_022i.jpg

4.2. Quality tests

Tests to check whether the products obtained are in conformity with the standards are called quality tests. In this project, there are 2 types of quality tests used.

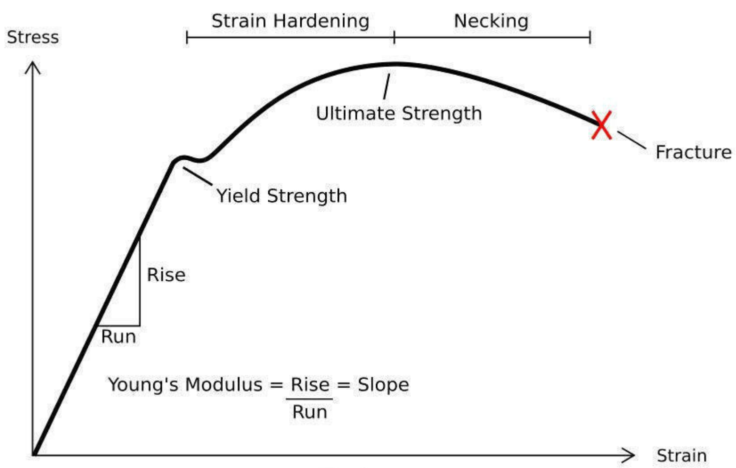
4.2.1. Tensile Testing

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test you can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on the test piece, you will very quickly determine how the material will react to forces being applied in tension. As the material is being pulled, you will find its strength along with how much it will elongate.



<u>Figure 5-</u> Tensile Test Machine
http://www.technologystudent.com/joints/matsind2.png

We can obtain different information directly through this test, such as maximum tensile stress, maximum elongation and decrease in area. From these data, properties such as Young's modulus, Poisson's ratio, yield strength and consolidation can be obtained. The stress-strain graph is generated as a result of these tests and the data result.



<u>Figure 6</u> *Stress-Strain graph example*
http://www.instructables.com/id/Steps-to-Analyzing-a-Materials-Properties-from-its/

4.2.2. Metallurgical Tests

Metallurgical testing and analysis is a valuable source of information for any industry working with metals. Laboratory testing's metallographic experts can examine samples to:

- Detect surface and internal flaws.
- Determine micro structural features.

- Evaluate heat treatments.
- Ensure conformance to required specifications.

The first step in metallurgical testing is test sample preparation. Samples are prepared in our metallurgical lab using precision cutting, mounting, grinding and polishing techniques, as well as etching when required. Second step is microscope examination of the part prepared. Depending on the region and the problem to be investigated in the material, the microscope to be used may change.

4.3. Comparison of the processes

Feature / Process	Cost	Shapeability	Accuracy	Process difficulty	Time	Risks
Lost wax	☹	🙂	🙂	☹	☹	☹
Sand mold	🙂	😐	☹	😐	😐	🙂
Die casting	😐	☹	🙂	🙂	🙂	😐

Table 2 *- Comparison of the processes*

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5. Conditions

- The most important thing is safety so this topic must find place on the first pages of the learning guides.
- About the budget, we don't have any specific amount of money because the material is going to be bought by the supervisors. If we need to buy something, for example the die casting mold, it's possible as soon as it is appropriate to the use it and is not so expensive.
- We are going to use Aluminium with a maximum of 17% silicon as the material.
- We do not know if we are going to purchase the die casting mold or if we are going to manufacture it. It depends on if the machines we have in the laboratory can manufacture the mold, if not we are going to buy the mold in the company Groupe Bernad - MGB
- We won't do the BONUS part, at least not in the first half of the project. The bonus part is another exercise in the master guide. It is about casting plates to test and analyse them, after rolling them. According to the decision made with the supervisors and the team members, we are going to produce plates with the sand mold and die casting mold just in case the plate fits correctly in the mold, if not we aren't doing it because it is not an option to create one specific mold for manufacturing plates. The bonus part, will maybe find place in the end of the project. We will decide about that at the mid-term-presentation.

6. Deliverables

The main deliverables are two learning guides for students. One of the guides is for bachelor students to teach them practically how to cast with different casting processes. The master guide is about teaching material and metallurgical testing. The bachelor and master packages includes, besides the respective guide a few other deliverables. Also, we must deliver management and EPS documents. The Bachelor guide will be for 12 students and has a workload of 4 hours. The master guide will also be for 12 Students, but it will have a workload of 8 hours. During the project, we can decide on our own, how to organise the teaching lessons.

6.1. Bachelor Package:

The learning guide for the bachelor students is about teaching them how to cast with the lost wax process, sand casting process and metallic die process. About the structure of the guides we can decide on our own, as soon as the main objective has been accomplished. We will probably assemble a short text with some pictures/photos and videos.

6.1.1. Lost wax

For the lost wax process part we have to ensure that the process is working well, because it has never been done before at the ENIT. Our deliverables for lost wax are a goodie (the piece is going to be manufactured) printed in wax and casted in aluminium, the CAD model of the goodie and the guide of this process. The students will only cast a single goodie for all the 12 students, so the manufactured piece is going to be for university.

6.1.2. Sand casting

Besides the guide for sand casting we have to deliver a goodie (different goodie than in the lost wax part) and three standardized parts for material testing (the material testing will take place in the master guide). The goodie and the three parts for testing we are going to bring are just samples. As we have specified in the conditions part, we have to produce all of the three parts for testing and the goodie in a single mold, and actually if it is possible a plate but from just one mold. Furthermore, we must deliver the CAD model of the goodie, the parts for testing and the mold.

Finally, we have to deliver one goodie and three standardized piece in wood or in polyurethane to make the mold in sand.

6.1.3. Die casting

For the metallic die process, we have to deliver the mold, and three standardized parts for material testing (the material testing will take place in the master guide). The parts for testing are the same parts like in the sand casting process. Also, the CAD model is the same so we just have to deliver the CAD model of the mold. It should be possible, that the students can cast all the three parts for testing in a single mold and as in sand casting if it's possible we are going to fit a plate for the bonus part.

6.2. Master Package:

The only deliverable in the Master Package is the guide. The guide should teach students how to test the three parts from sand casting and the three parts from metallic die. The guide should be about tensile test and metallurgical test. After that, the students will have to compare the parts of sand casting with the parts of metallic die. Like in the bachelor guide, the master guide will be a compilation of a short text, pictures/photos and videos.

6.3. Management documents:

We have to deliver all the documents about how we organized our project team while the EPS. We will deliver documents like the requirement documents, a Gantt Chart, a WBS and some other documents, which helps us to make a proper project management plan.

6.4. EPS documents:

Moreover, we will deliver a mid-term report and a final report about our work and project management. For the reports, we will also prepare two presentations.

7. List of deliverables

In order to specify the deliverables, we have listed them in groups according to the process they belong:

Handbook

1. Handbook for bachelor students (wax lost casting, sand mold and die casting).
2. Handbook for master students (quality tests).
3. Graphic document for bachelor students (wax lost casting, sand mold and die casting).
4. Graphic document for master students (quality tests).

Lost wax process

5. First lost wax part.
6. CAD model for lost wax goodie.

Sand casting

7. 3 tensile test samples and 12 goodies (from sand casting).
8. 3 tensile test samples models (polyurethane).
9. Sand casting goodie model (polyurethane).
10. CAD model of the sand mold.
11. CAD model for sand mold goodie.
12. CAD model of the tensile test sample.

Die casting

13. CAD model of the die casting mold.
14. CAD model of the tensile test sample.
15. Die casting mold.
16. 3 tensile test samples.

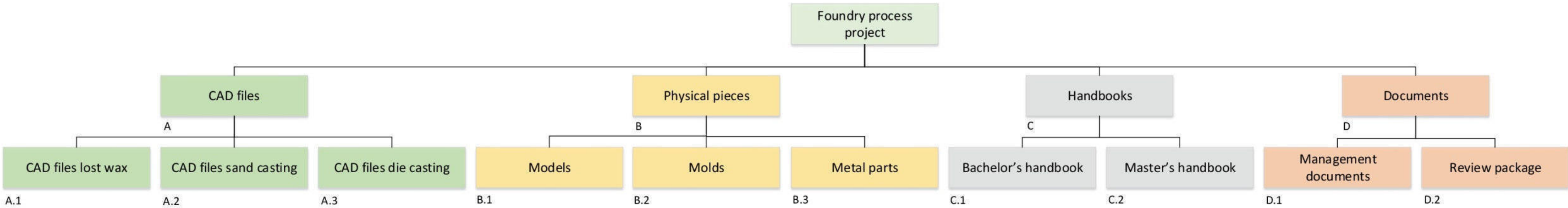
Bonus part

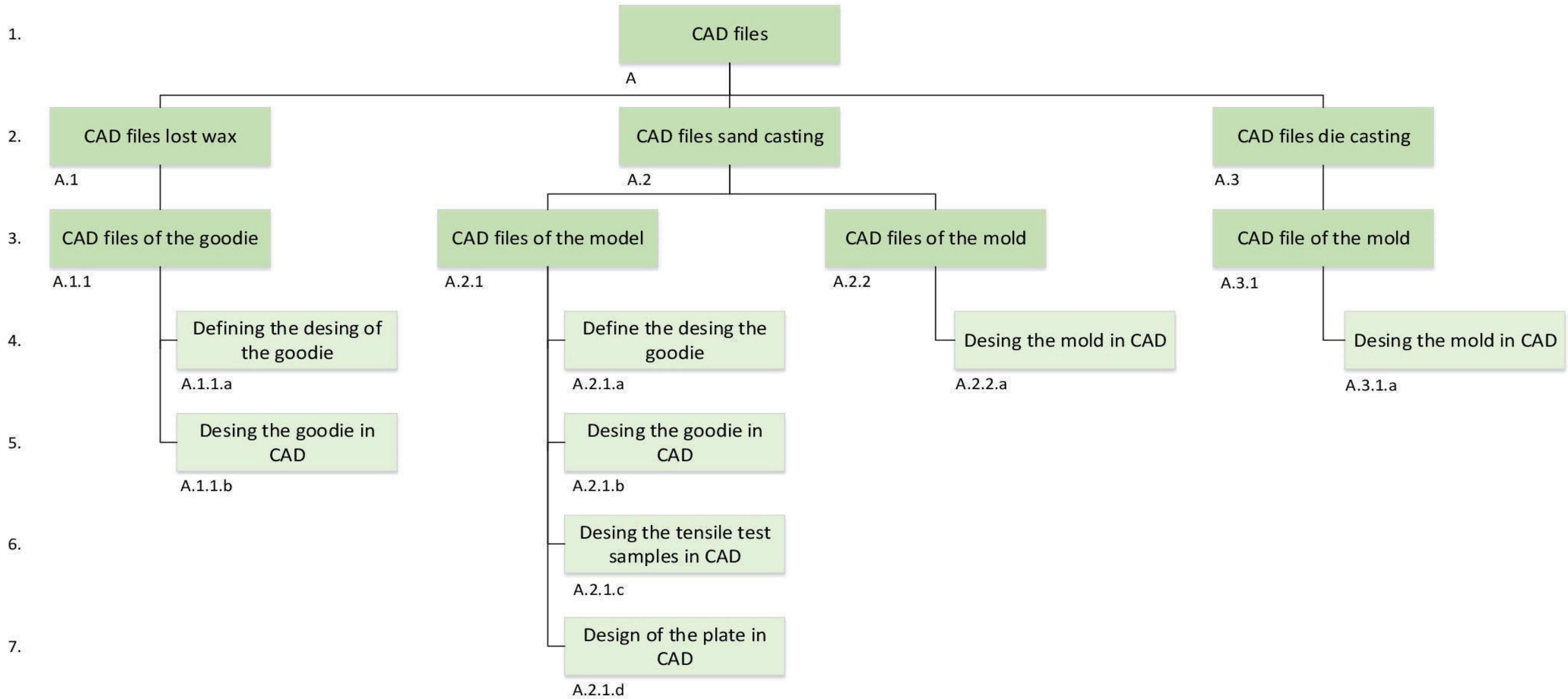
17. Bonus part (in case fits in the mold).

8. Exclusions

- In the project, we won't do a guide for teachers, just two guides for students.
- We won't translate the guide into French. We will only deliver guides in English.
- We are not going to print all the lost wax pieces, just the first one.
- Just one goodie created during lost wax process because of the price.

9. WBS


Foundry process project
CAD files
A
Physical pieces
B
Handbooks
C
Documents
D
CAD files lost wax
A.1
CAD files sand casting
A.2
CAD files die casting
A.3
Models
B.1
Molds
B.2
Metal parts
B.3
Bachelor's handbook
C.1
Master's handbook
C.2
Management documents
D.1
Review package
D.2


1.
2.
3.
4.
5.
6.
7.
CAD files
A
CAD files lost wax
A.1
CAD files sand casting
A.2
CAD files die casting
A.3
CAD files of the goodie
A.1.1
CAD files of the model
A.2.1
CAD files of the mold
A.2.2
CAD file of the mold
A.3.1
Defining the desing of the goodie
A.1.1.a
Desing the goodie in CAD
A.1.1.b
Define the desing the goodie
A.2.1.a
Desing the goodie in CAD
A.2.1.b
Desing the tensile test samples in CAD
A.2.1.c
Design of the plate in CAD
A.2.1.d
Desing the mold in CAD
A.2.2.a
Desing the mold in CAD
A.3.1.a

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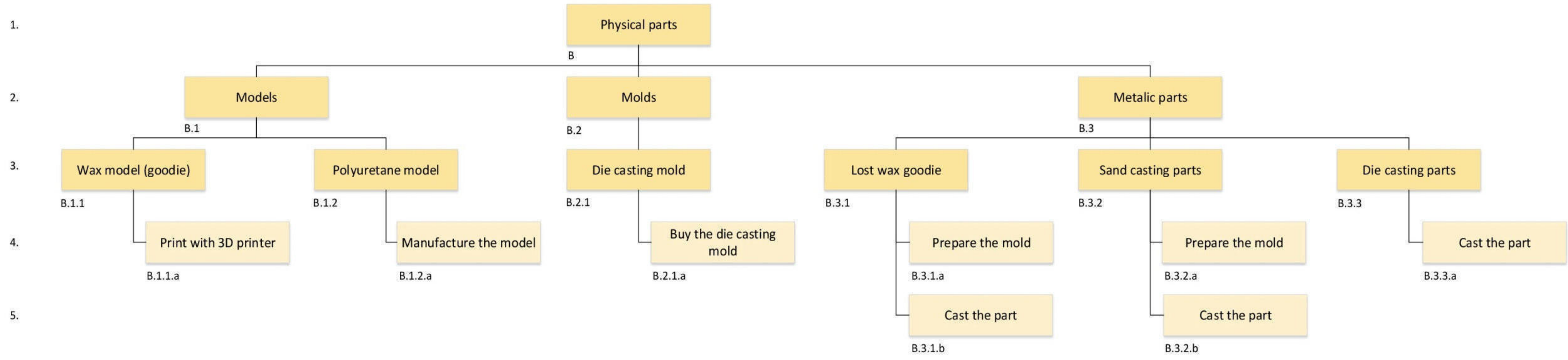
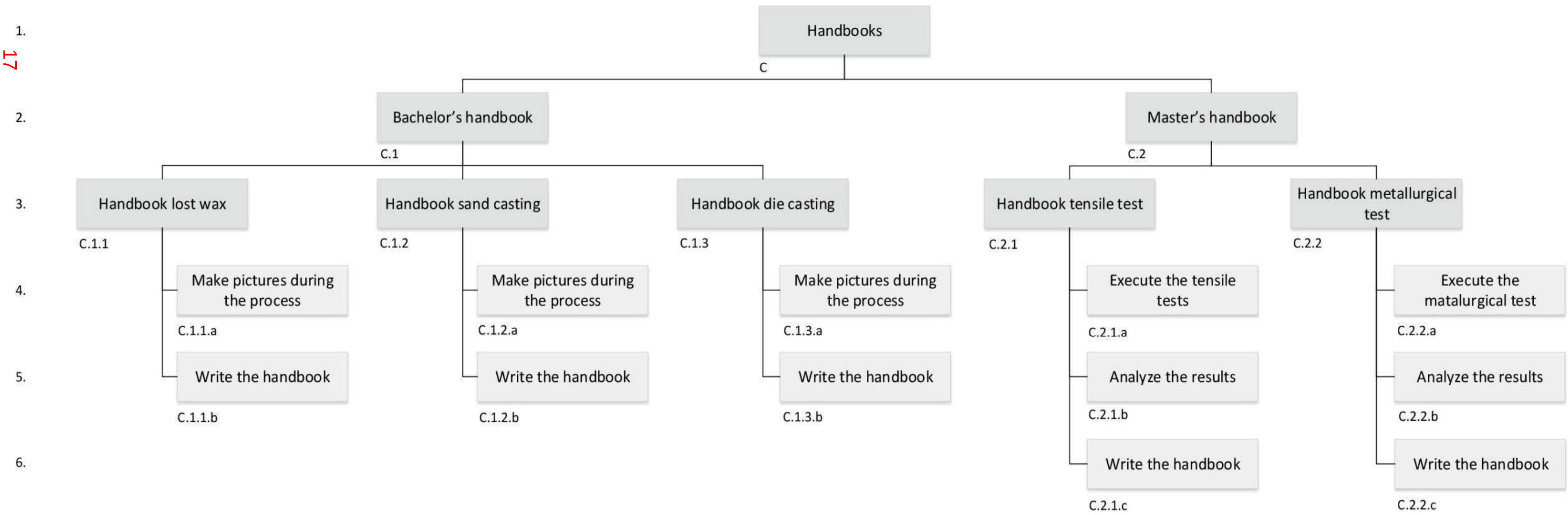
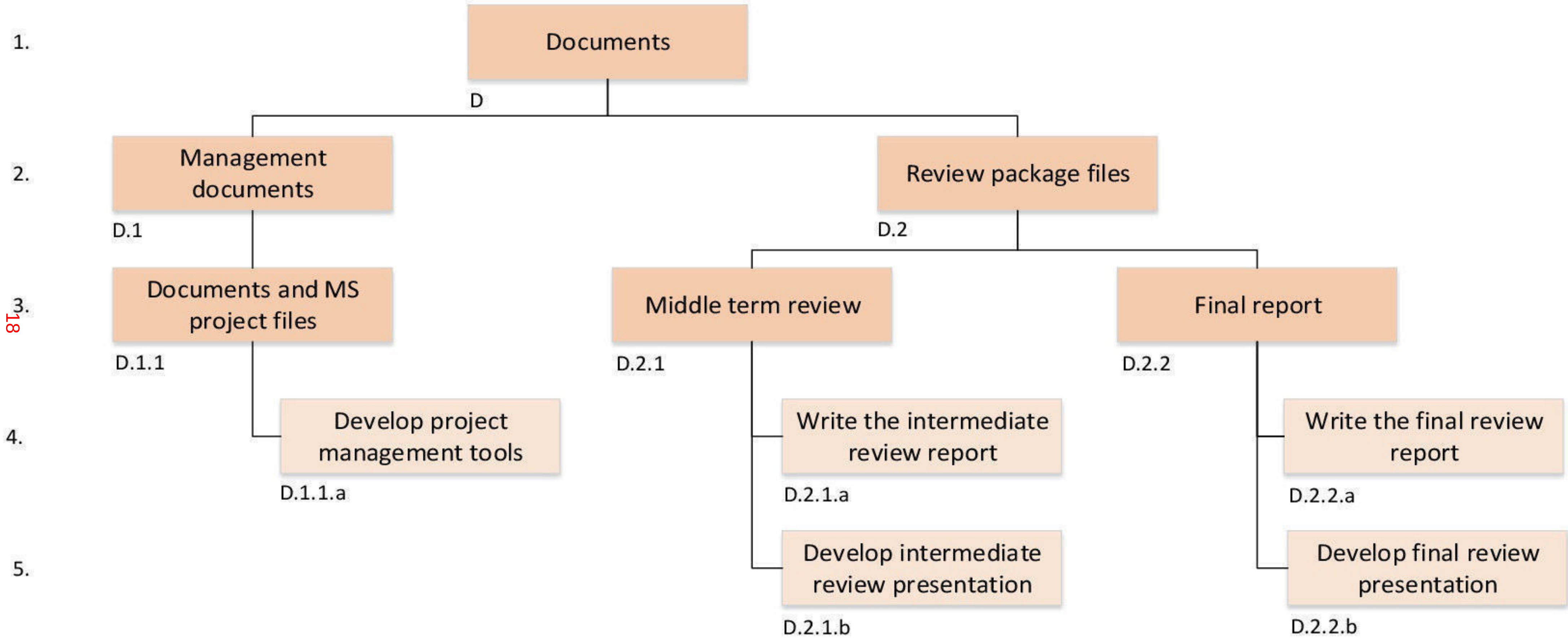

1.
2.
3.
4.
5.
Physical parts
B
Models
B.1
Molds
B.2
Metalic parts
B.3
Wax model (goodie)
B.1.1
Polyuretane model
B.1.2
Die casting mold
B.2.1
Lost wax goodie
B.3.1
Sand casting parts
B.3.2
Die casting parts
B.3.3
Print with 3D printer
B.1.1.a
Manufacture the model
B.1.2.a
Buy the die casting mold
B.2.1.a
Prepare the mold
B.3.1.a
Prepare the mold
B.3.2.a
Cast the part
B.3.3.a
Cast the part
B.3.1.b
Cast the part
B.3.2.b


1.
2.
3.
4.
5.
6.
Handbooks
C
Bachelor's handbook
C.1
Master's handbook
C.2
Handbook lost wax
C.1.1
Handbook sand casting
C.1.2
Handbook die casting
C.1.3
Handbook tensile test
C.2.1
Handbook metallurgical test
C.2.2
Make pictures during the process
C.1.1.a
Make pictures during the process
C.1.2.a
Make pictures during the process
C.1.3.a
Execute the tensile tests
C.2.1.a
Execute the matalurgical test
C.2.2.a
Write the handbook
C.1.1.b
Write the handbook
C.1.2.b
Write the handbook
C.1.3.b
Analyze the results
C.2.1.b
Analyze the results
C.2.2.b
Write the handbook
C.2.1.c
Write the handbook
C.2.2.c


1.
2.
3.
4.
5.
Documents
D
Management documents
D.1
Review package files
D.2
Documents and MS project files
D.1.1
Middle term review
D.2.1
Final report
D.2.2
Develop project management tools
D.1.1.a
Write the intermediate review report
D.2.1.a
Develop intermediate review presentation
D.2.1.b
Write the final review report
D.2.2.a
Develop final review presentation
D.2.2.b

10. Risks Matrix

10.1. Management risks

1) Inaccessibility of a team member.
2) High cost (process, materials).

10.2. Technical risks

a) Not be able to build a wax model by any method available. There are two methodologies available for 3D printing in wax.
b) Cannot build the lost wax process mould.
c) Cannot manufacture the sand casting process part.
d) The die casting mold won't be on time.
e) Don't have enough time to cast all the pieces because problems during processes.
f) The casting processes take too much time to be done in a practical lesson.
g) 2 clients (possible needs expression conflict).Cannot manufacture the die casting mold.
h) Not be able to manufacture the different samples in polyurethane.

		IMPACT		
		MINOR	MODERATE	MAJOR
LIKELIHOOD	LIKELY	MODERATE d,	HIGH	HIGH
	MODERATE	LOW f	MODERATE 2,b	HIGH
	UNLIKELY	LOW 3,h	LOW 1,a	MODERATE c,e,i

Table 3 *- Risk Matrix.*

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10.3. Solutions to the risks

1. If one of the members isn't able to come one day, that person is going to make up for those hours lost. In case one member is not coming for more than one day we are going to distribute the work of that person between the other members.
2. We will discuss with the technical supervisors the way to make the cost lower.

a) If any of the two methods we know can be printed in wax, we will study other possibilities because this process has never been done in ENIT but it has been done in other places, so we know it's possible.
b) We will check for another method for leaving the wax of the mold or even try changing the sand.
c) If the part it's difficult to be manufactured we are going to simplify it to make it easier to manufacture.
d) There is no big problem if the mold for die casting isn't on time because our supervisors could manufacture it with our CAD files.
e) According to our technical supervisors as soon as we deliver all the CAD files they can cast and manufacture all parts are needed.
f) There is no problem if practical lessons are a little bit longer, we can even propose to do the practical lessons in two days.
g) In this situation we have to deal with different opinions and then make an agreement of what we think it's better, always being respectful of the other opinions.
h) An external company (MGB) could manufacture this mold if we aren't able to do it in ENIT laboratory.
i) This problem shouldn't pass because there is a lot of different machines in the laboratory, and our technical supervisors have a lot of knowledge about manufacturing, but in case we cannot manufacture the different samples in polyurethane we will try with another material, another method to manufacture or even another shape.

11. Task list

WBS	Task name	Workload	Responsible person	Resource	
A	**CAD files**	**300**			
A.1	**CAD files the lost wax**	**100**			
A.1.1	Cad files for the goodie	100			
A.1.1.a	Defining the design of the goodie	20	David	D, J, M, S, O	
A.1.1.b	Design the goodie in CAD	80	Oriol	O, J, D	
A.2	**CAD files sand casting**	**150**			
A.2.1	CAD files for the model	110			
A.2.1.a	Define the design of the goodie	20	David	D, J, M, S, O	15%
A.2.1.b	Design the goodie in CAD	80	Marvin	S, M	
A.2.1.c	Design the test pieces in CAD	10	Semih	S, M	
A.2.1.d	Design of the plate in CAD				
A.2.2	CAD files of the mold in cad	40			
A.2.2.a	A design of the mold in cad	40	Semih	S, M, O	
A.3	**CAD files die casting**	**50**			
A.3.1	Cad files of the mold	50			
A.3.1.a	Design the mold in CAD	50	Justyna	D, J	
B	**Physical parts**	**350**			
B.1	**Models**	**150**			
B1.1	Wax model (Goodie)	60			
B.1.1.a	Print with 3D printer	60	Justyna	D, J, M, S, O	
B.1.2	Polyurethane model	90			
B.1.2.a	Manufacture the model	90	David	J, S, O	
B.2	**Molds**	**30**			
B.2.1	Die casting mold	30			
B.2.1.a	Buy/make the die casting mold	30	Marvin	D, M	
B.3	**Metallic pieces**	**170**			
B.3.1	Lost wax goodie	80			18%
B.3.1.a	Prepare the mold	60	Oriol	D, J, M, S, O	
B.3.1.b	Cast the piece	20	Marvin	D, J, M, S, O	
B.3.2	Sand casting pieces	60			
B.3.2.a	Prepare the mold	40	Semih	D, J, M, S, O	
B.3.2.b	Cast the piece	20	Semih	D, J, M, S, O	
B.3.3	Die casting pieces	30			
B.3.3.a	Cast the piece	30	Semih	D, J, M, S, O	
C	**Handbook**	**430**			22%
C.1	**Bachelor's handbook**	**210**			

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C.1.1	Handbook lost wax	70			
C.1.1.a	Make pictures during the process	10	Oriol	Oriol	
C.1.1.b	Write the handbook	60	Justyna	J	
C.1.2	Handbook sand casting	80			
C.1.2.a	Make the pictures during the process	10	Oriol	Oriol	
C.1.2.b	Write the handbook	70	David	D	
C.1.3	Handbook die casting	60			
C.1.3.a	Make the pictures during the process	10	Oriol	Oriol	
C.1.3.b	Write the handbook	50	Marvin	M	
C.2	**Master handbook**	**220**			
C.2.1	Handbook tensile test	110			
C.2.1.a	Execute tensile test	20	Semih	O, J	
C.2.1.b	Analyze the results	20	Semih	O, J	
C.2.1.c	Write the handbook	70	Semih	O	
C.2.1	Handbook metallurgical test	110			
C.2.1.a	Execute metallurgical test	20	Oriol	S, D, M	
C.2.1.b	Analyze the results	20	Oriol	S, D, M	
C.2.1.c	Write the handbook	70	Oriol	S	
D	**Documents**	**880**			45%
D.1	**Management document**	**600**			
D.1.1	Documents and MS file	600			
D.1.1.a	Defining the project	400	Justyna, David, Oriol, Semih	D, J, M, S, O	
D.1.1.b	Project management activities	200	Marvin	D, J, M, S, O	
D.2	**Review package files**	**280**			
D.2.1	Middle term review	100			
D.2.1.a	Write the intermediate report	80	David	D, J, M, S, O	
D.2.1.b	Develop intermediate review presentation	20	Semih	D, J, M, S, O	
D.2.2	Final report	180			
D.2.2.a	Write the final report	140	Justyna	D, J, M, S, O	
D.2.2.b	Develop final review presentation	40	Oriol	D, J, M, S, O	

Table 4 *- Task list.*

Responsibility					
Person	A	B	C	D	Total
David	40	90	70	180	380
Justyna	50	60	60	240	410
Marvin	80	50	50	200	380
Semih	50	90	110	120	370
Oriol	80	60	140	140	420

Table 5 *- Responsibility between team members (hours).*

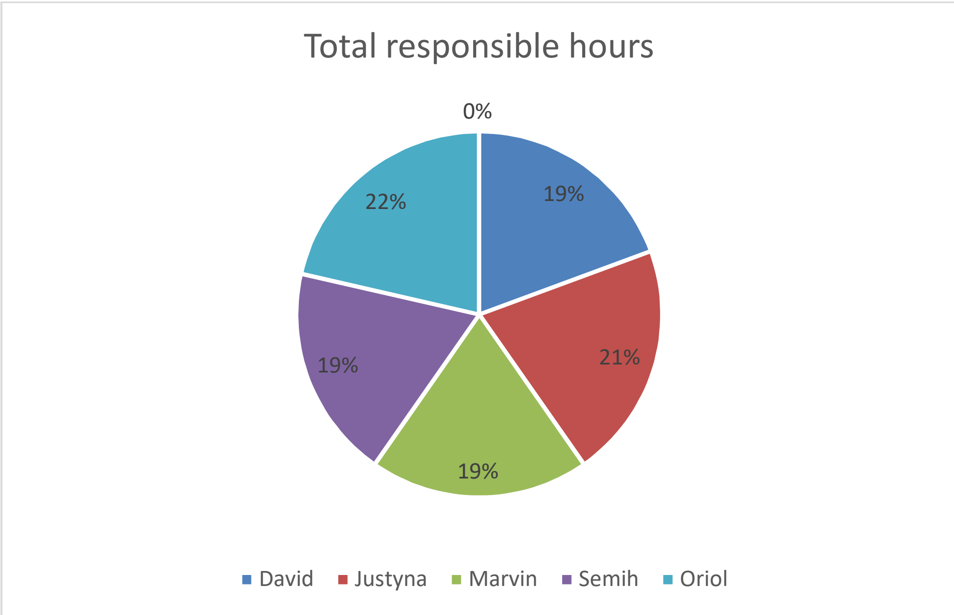

Chart 1 *- Total responsible hours.*

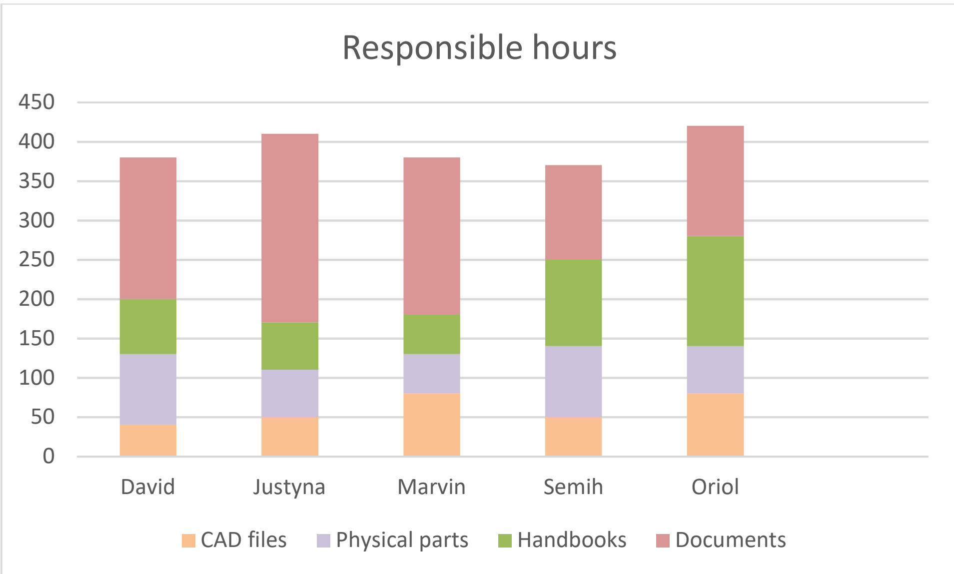

Chart 2 *- Responsible hours in bar chart.*

12. Priorities

According to our deliverables and the aim of the project we can define our priorities matrix, in the priority matrix you can find all the activities with its WBS code:

12.1. Plan A

MANDATORY	Handbooks for bachelor students (C.1.1, C.1.2, C.1.3) Handbooks for master students (C.2.1, C.2.2) First lost wax part (B.1.1) CAD model for lost wax goodie (A.1.1) 3 tensile test samples and 12 goodies (from sand casting) (B.3.2) 3 tensile test samples (polyurethane) (B.1.2) Sand casting goodie (polyurethane) (B.1.2) CAD model of the sand mold (A.2.2) CAD model for sand mold goodie (A.2.1) CAD model of the tensile test sample (A.2.1) CAD model of the die casting mold (A.2.2) CAD model of the tensile test sample (A.2.1) 3 tensile test samples (from die casting) (B.3.3) Management documents (D.1) Review package files (D.2)
OPTIONAL	Graphic documents for bachelor students (C.1.1a, C.1.2.a, C.1.3.a) Graphic documents for master students Die casting mold (B.2.1) Bonus part (in case fits in the mold) (B.3.2, B.3.3)

Table 6 *-Plan A.*

12.2. Plan B

MANDATORY	Handbooks for bachelor students (C.1.1, C.1.2, C.1.3) Handbooks for master students (C.2.1, C.2.2) First lost wax part (B.1.1) CAD model for lost wax goodie (A.1.1) 3 tensile test samples and 12 goodies (from sand casting) (B.3.2) 3 tensile test samples (polyurethane) (B.1.2) Sand casting goodie (polyurethane) (B.1.2) CAD model of the sand mold (A.2.2) CAD model for sand mold goodie (A.2.1) CAD model of the tensile test sample (A.2.1) CAD model of the die casting mold (A.2.2) CAD model of the tensile test sample (A.2.1) 3 tensile test samples (from die casting) (B.3.3) Management documents (D.1) Review package files (D.2)

Table 7 *-Plan B.*

13. Gantt

WBS	WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6	WEEK 7	WEEK 8	WEEK 9	WEEK 10	WEEK 11	WEEK 12	WEEK 13	WEEK 14	WEEK 15	WEEK 16
A																
A.1																
A.1.1																
A.1.1.a							100%									
A.1.1.b							100%									
A.2																
A.2.1																
A.2.1.a							100%									
A.2.1.b							50%	100%								
A.2.1.c																
A.2.1.d																
A.2.2																
A.2.2.a																
A.3																
A.3.1																
A.3.1.a																
B																
B.1																
B1.1																
B.1.1.a																
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B.3.3.a																
C																
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C.2.1.a																
C.2.1.b																
C.2.1.c																
C.2.1																
C.2.1.a																
C.2.1.b																
C.2.1.c																
D																
D.1																
D.1.1																
D.1.1.a	25%	50%	75%			100%										
D.1.1.b	21%	43%	64%			85%										
D.2																
D.2.1																
D.2.1.a																
D.2.1.b																
D.2.2																
D.2.2.a																
D.2.2.b																

Appendix 2

WBS

In the chapter WBS, we show in contrast to the according section in the Report, another old version of our WBS and explain why we decided that the WBS you can see in the report is the best option to present our deliverables and tasks clearly. You can see the whole WBS and after, bigger pictures of the different sections.

WBS

The work breakdown structure has many benefits to defining and organizing the project work. As the project executes, specific sections of the WBS can be tracked. The project WBS can be used to identify potential risks in each project. If the WBS has a branch that is not well defined then it represents a scope definition risk. During the management process, we prepared several versions of the WBS. The first one was divided into three main commitments for the Bachelor pack, Master pack and Documents. The main disadvantage of the WBS was that the goals were incorrectly defined. We were focus only on deliverables for technical process, which we needed to prepare. Our main aim - handbook, was used only like sub-deliverable. It does not present a way to achieve aim. For an identification type of group, we used colour for each one. The problem was with the schematic presentation, it was unreadable and impossible to present the overall picture. The structure was too big and used colours made it difficult to read.

After presenting this version on a meeting with the management supervisor we decided to change a method, because the WBS should present our aims, and ways how it is possible. Our group decided to divide WBS into four main categories and named:

- CAD files
- Physical pieces
- Handbooks
- Documents

The following guidelines should be considered when the WBS was creating:

- The top level represents the final deliverable or project.
- Sub-deliverables contain work packages to the biggest deliverables
- Activates create a sub-deliverable.
- Elements of the WBS are defined to different level.

The new WBS can be found in the according section of the report

In our work, we used symbols to help identify items on the WBS and other parts of the work.

Following the signs:

A-activity

D-devilerables

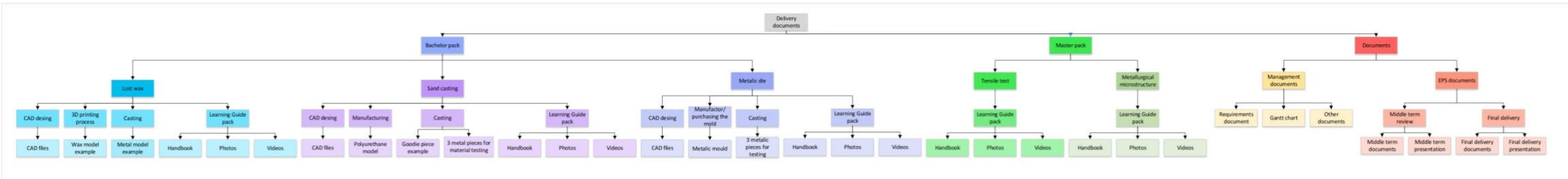


Figure 1: Whole WBS

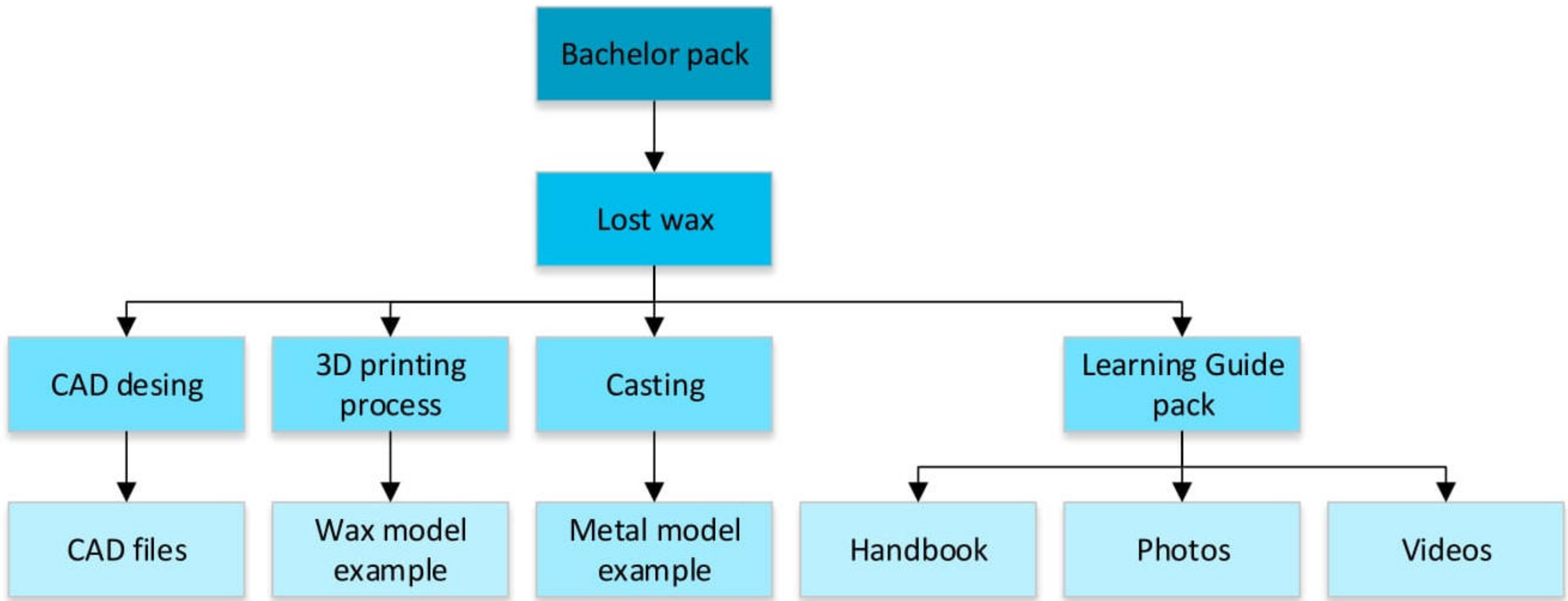


Figure 2: WBS - Bachelor pack I

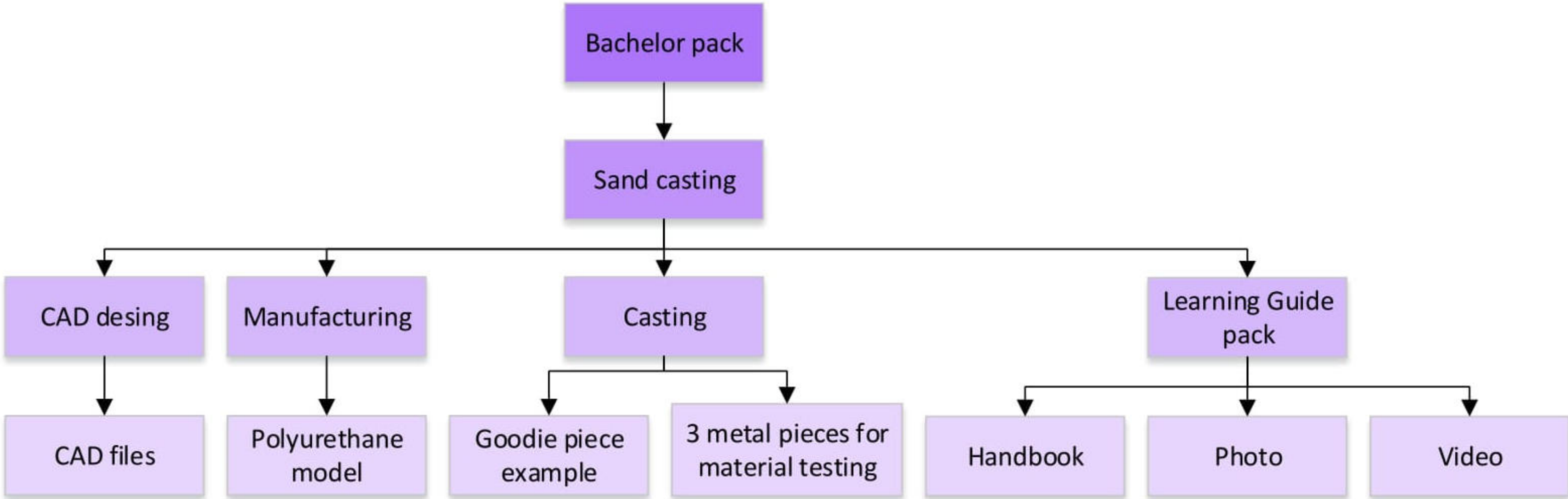


Figure 3: WBS - Bachelor pack II

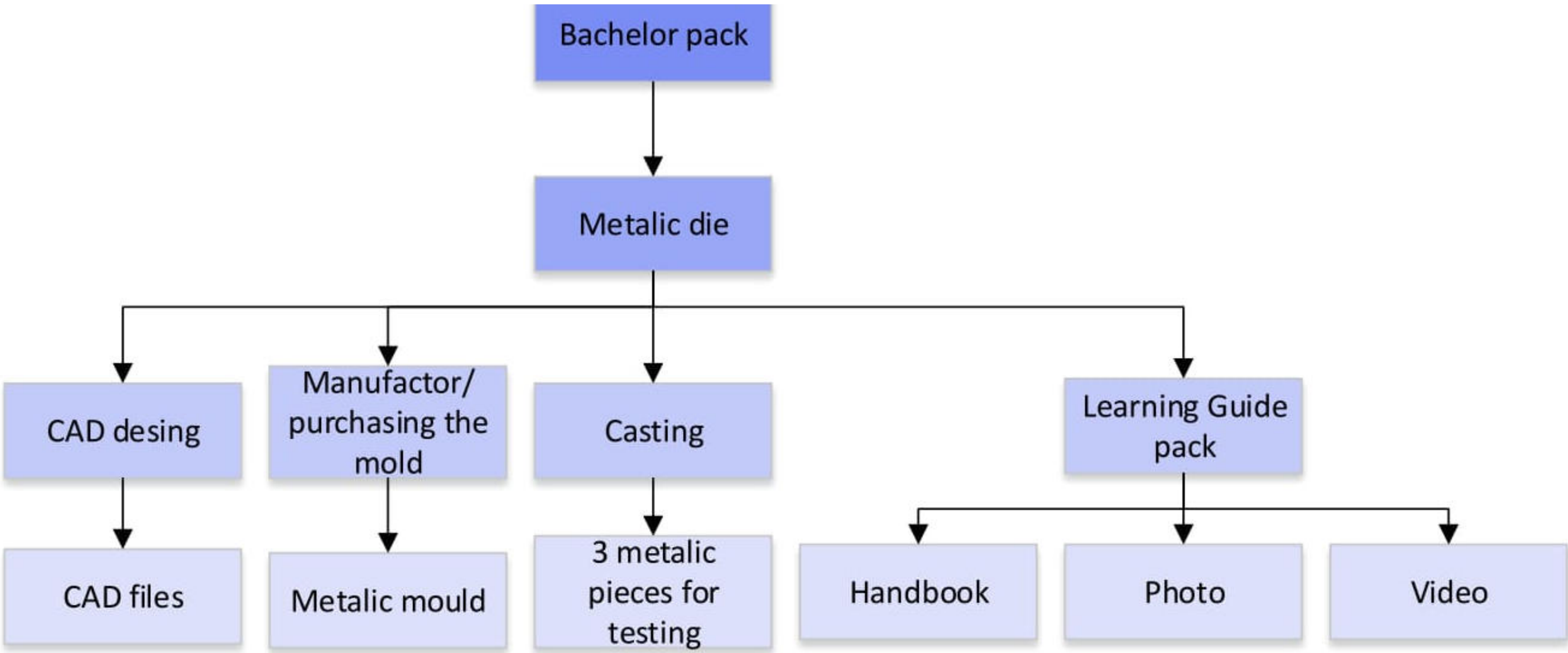


Figure 4: WBS - Bachelor pack III

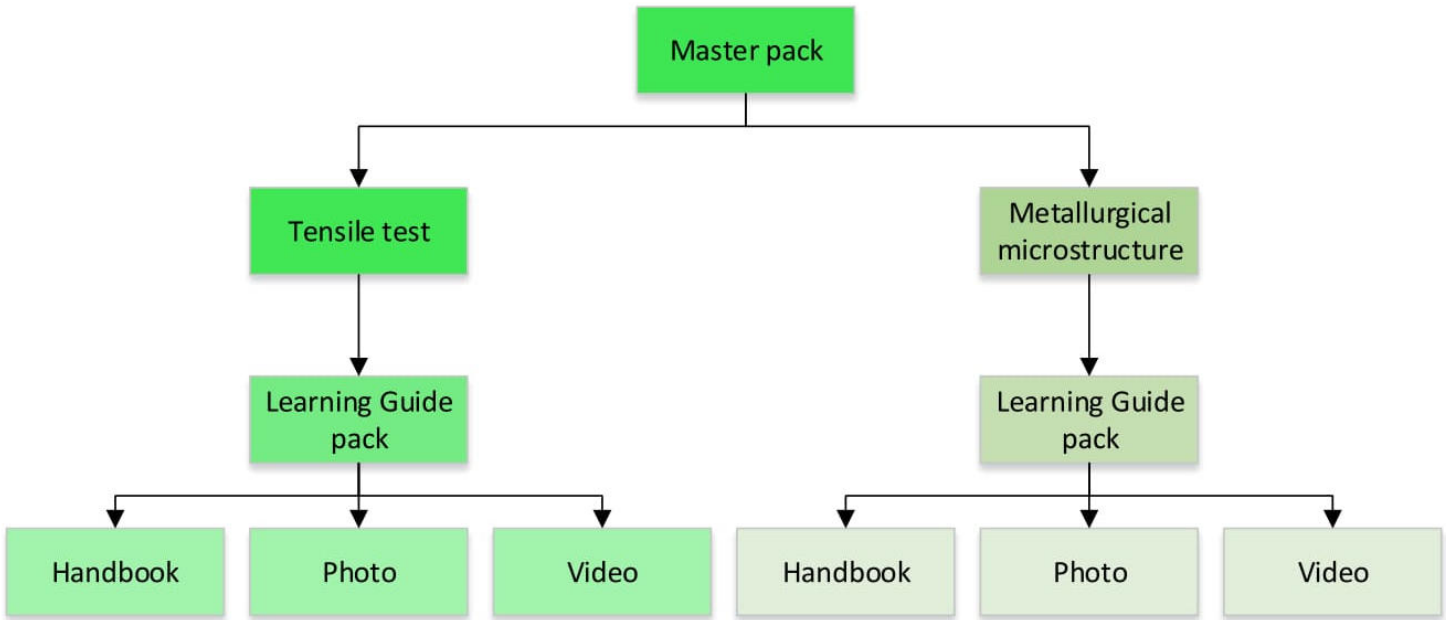


Figure 5: WBS - Master pack

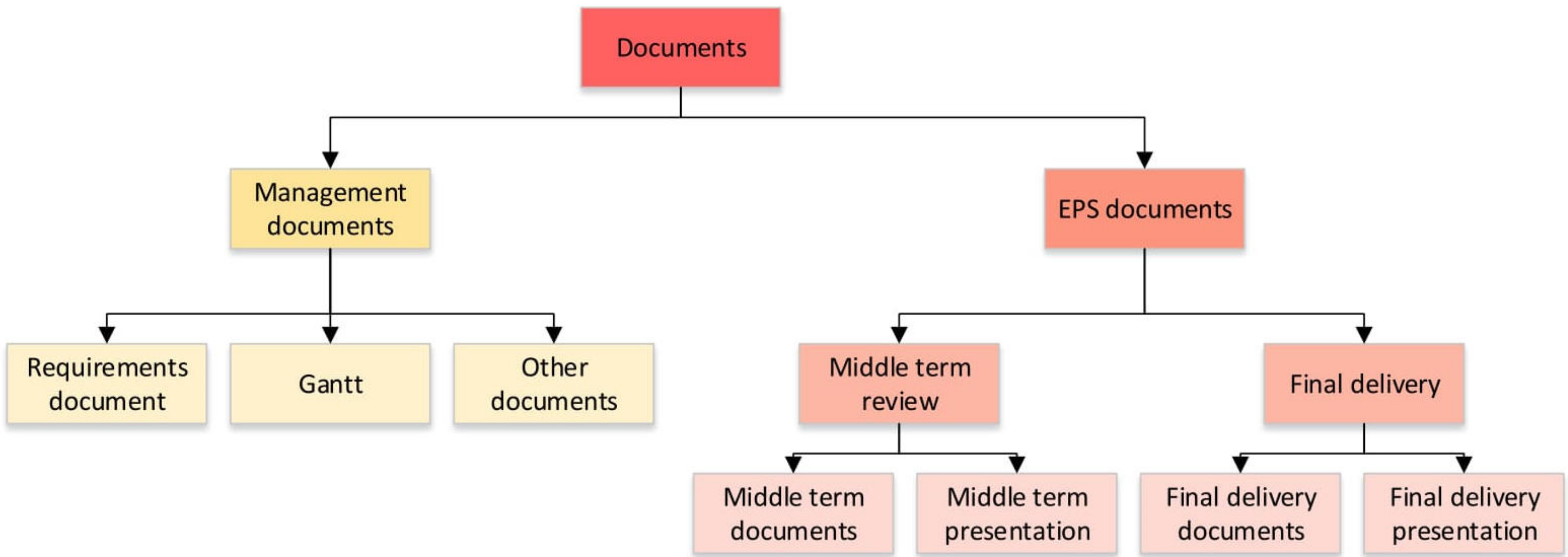


Figure 6: WBS - Documents

Appendix 3

Gantt

In the chapter Gantt, you can find pictures of our Gantt-diagram, we created in MS Projekt. We divided the Gantt in 4 different topics: CAD files, Physical parts, Handbooks and Documents. After. You can also see the important milestones we set in the beginning of the project.

Figure 1: Gantt - CAD files

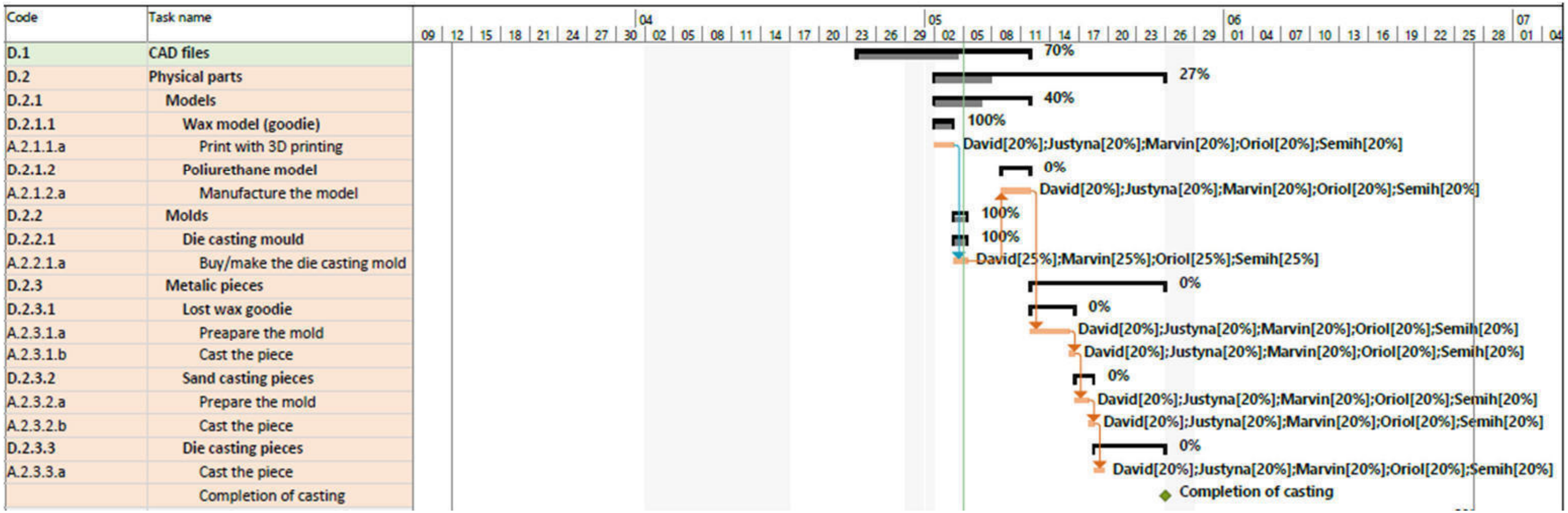


Figure 2: Gantt - Physical parts

Figure 3: Gantt - Handbook

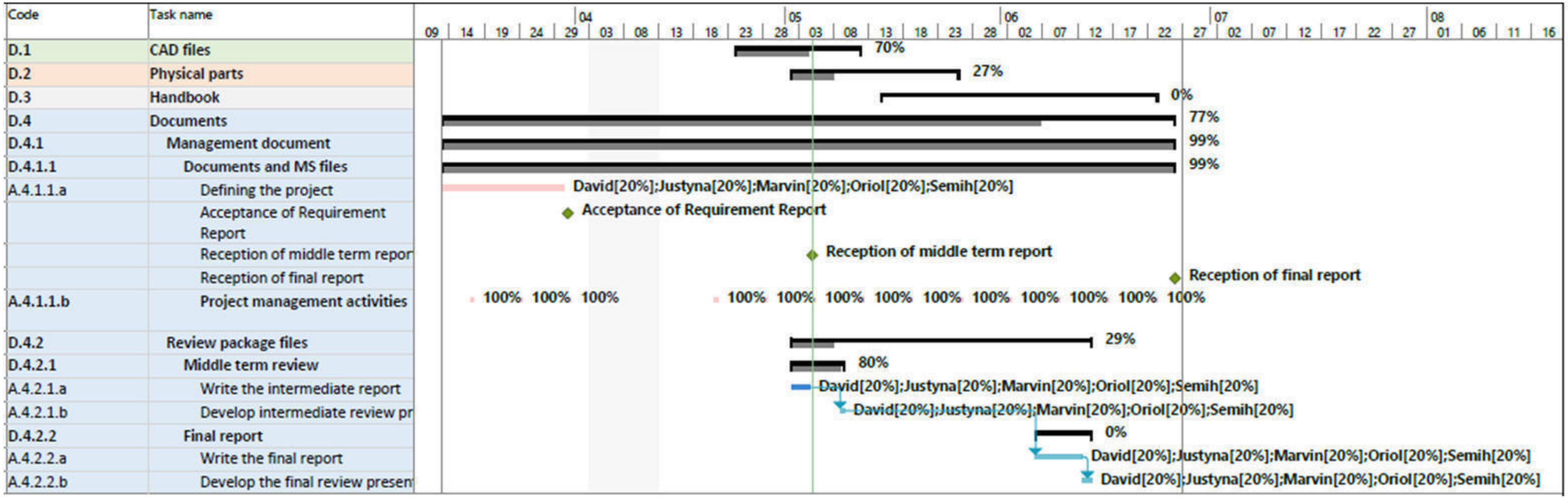


Figure 5: Gantt - Documents

Figure 4: Gantt - Milestones

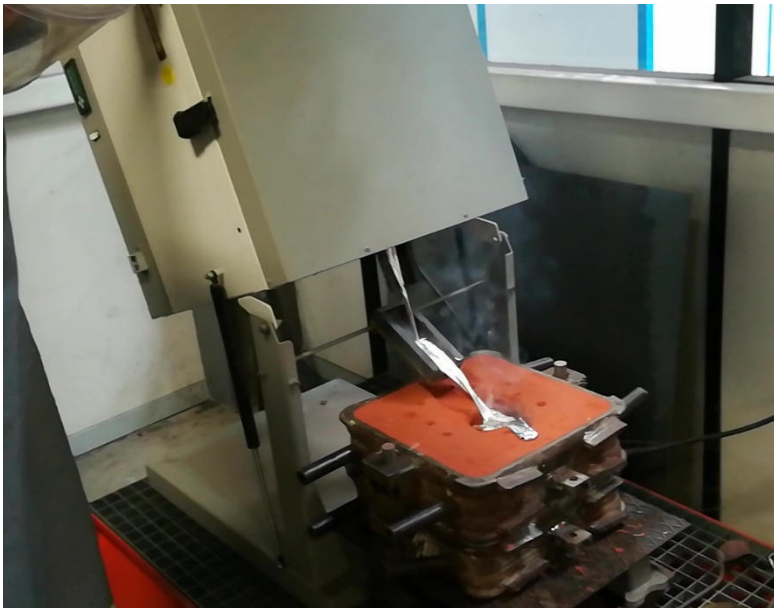
Appendix 4

Bachelor Handbook

In this section of the appendix, you can find the Bachelor Handbook, one of our main deliverables. The Bachelor Handbook is about the sand casting process and the lost wax process. It consists of some safety rules, theoretical knowledge of the processes, the structure of the practical learning guide and step by step instructions.

Bachelor Handbook

Practical lesson for casting processes



Content of the Handbook

1. Introduction and Safety

The Bachelor handbook was developed for both the theoretical knowledge and the practical part of practical work in the laboratory. It is based on the knowledge and experience gained by the 5-person group of students of the European Project Semester. We hope that our knowledge gained during the experiments will allow you to learn effectively.

A special thank goes to our technical supervisors Francois Grizet, Yannick Balcaen and Guillaume Mazenc, as well as our management supervisor Philippe Fillatreau for their advice and guidance during the project. We would not be able to complete the project without them.
We would also want to express our greatest gratitude to all the teachers and colleagues from the EPS for all their help and support during these months.

Before you can go to the laboratory and start casting, it is mandatory to read the whole Handbook.

Safety rules

- Always wear the protection clothes you get provided with by your teachers
- Keep Emergency exits easily accessible
- Report unsafe conditions to your teacher
- Be aware of your surroundings
- Do not run in the laboratory
- Use tools and machines properly
- Be always concentrated and take a break if necessary

2. Structure of the learning session

The Bachelor Handbook consists of two parts. There is a part for the lost wax process and the sand casting process. Both parts, the sand casting part and the lost wax part, will contain theoretical knowledge about the process and explain how to perform it step by step. The Bachelor Handbook is designed for twelve Students and it will take a time of about eight hours. With the lost wax process, you will cast a goodie for the teachers and with the sand casting process, you will cast three parts for tensile test and metallurgical test, which are getting performed by master students and twelve bottle openers for yourself to keep.

We decided to split the practical learning sessions on three days. This part of the Handbook is just to explain you the structure of the lessons. How to do all the steps is explained in the respective part.

Day 1: For the work of the first day you will need about three hours. In the beginning, all twelve students prepare the mold for the lost wax process. After they split in three groups of four students. Every group is preparing one mold. One group make the mold for the three testing parts and the other two groups prepare a mold to for six bottle openers.

Day 2: The second day is divided up on two sessions of one hour. In the morning, you should turn on two furnaces. One to heat the lost wax mold and evaporate the wax and the second one to melt the aluminium you are going to use for the casting process.

In the afternoon, there is another short session. Here you will perform the two casting processes.

Day 3: For the last day, we also planned three hours. You must destroy the four molds to get the casted production. After you will cut out the parts and grind them. If you finished the work, we planned a discussion for you. You should talk about your experience, your mistakes and the things you have done well for 20-30 minutes.

Finally, you can deliver the lost wax goodie and the parts for testing to your teacher, take your bottle opener and try it at the Foyer or somewhere else.

Sand mold handbook

3. Sand mold casting

3.1 Basic information

Sand casting is a popular and easy-to-use casting process for different kind of metals and alloys. Most of the cast metals and alloys can be used for the sand casting process. Prepared castings can be of various shapes and sizes. In this way, various components can be produced. The size of the product can vary extremely. It is possible to cast very small parts and very big parts as well. Some examples of industrial components, made with sand casting are engine blocks, machine tool bases pump housings and valves.

The object with is getting produces by the process is called casting. Typically, this name is used for items that do not require mechanical processing. Typically, the pattern differs in detail from the final form of casting, due to the need to consider the various technological elements relevant for the correct execution of complex castings.

- Casting - a metal product made by pouring melted metal in a casting mold
- Casting mold - a set of elements, that form a cavity of the shape of the part you are going to cast, when they are assembled.

Model – A Model is a part, which is manufactured in wood, steel, polyurethane or another material with the same shape of the part you are going to cast. It is needed to prepare the mold for the casting process.

In the following sections, you will find a table of all the equipment you need to perform the whole process, from the mold preparation to the final product. After, there are all the required calculations about the design of the mold. In the End, you will find step-by-step instructions. In this section, you will learn how to prepare the mold, melt the aluminium and finally, cast.

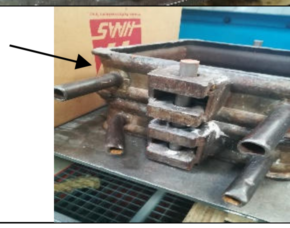
You will perform the process with an aluminium alloy with about six percent of silicon and three percent of cupper. In has a density of about 2870 kg/m^3 and a melting temperature of 580°C. Normally, the melting temperature of Aluminium is higher, but it is possible to set it down with alloying it with silicon up to 12 %.

The sand you will use is a special oil bound sand. It is mainly used for casting heavy metals or cast-iron materials with a thin to middle thickness. The first layer should be pressed lightly, after it is possible to condense the sand strongly. Do not use water for the sand.

- Compressive strength: 1300 g/cm^2
- Shear strength: 400 g/cm^2
- Gas permeability: 18
- Flowability 35 %
- Grain fineness 140 AFS
- Medium grain size 0,09 mm

3.2 Equipment

Before starting work, make sure you have all the tools you need. This will allow you to perform the process safely for you and other people in the lab.

The drag (bottom half)	
The cope (top half)	
The alignment pins	
Model (created earlier in CATIA and manufactured)	
Oil bound sand	
Skewer	
Wooden plank	

Protective clothing	  
Talc powder	 
Beater	

Table 1: Equipment for sand casting

3.3 Step-by-Step instructions

Here you have step by step instructions to prepare the mold, execute the casting process and get out the final parts.

3.3.1 Mold preparation

1.

For the first step, you need the model of the part you are going to cast and the drag, the lower part of the sand mold case.

You place the drag on the working surface and place the model in the middle of it.

Figure 1: Mold with model

2.

Now you need to sprinkle some of the chalk powder on the working surface and especially on the model to avoid, that the sand stick on the model. That makes it easier, to get out the model to form the cavity for the melted aluminium in a later step.

Figure 2: Mold with talk powder

3.

In this step, you must start filling the case with sand.
First, cover the working furnace and the models with sand and press it firmly with the hands. After, you should tramp the sand down with the beater to make it solid. Do not fill the case completely, use small portions of sand and press it layer by layer to fill the hole drag.

Figure 3: First layer of sand

4.

Your next step is to level the sand, when the whole case is filled with sand, by using a wooden plank. The sand should have the same level as the upper edge of the case. Remove the excess of sand by striking over the sand with the wooden plank.

Figure 4: Use of wooden plank

5.

Now, flip the case over carefully.
This allows you to pull out the parts and keep a cavity in the sand.

Figure 5: Bottom half of the mold

6.

With the skewer and the spoon, you can pull out the parts carefully. You might get the problem, that you also pull out the sand in the edges and holes. The solution is to pull out the part very slowly and carefully and try to hold down the edges of sand. Press the sand just very lightly.
After this step, the first half of the mold preparation is done.

Figure 6: Use of Skewer

7.

To prepare the second half of the mold, you need to fill the top half, the cope, with sand. First, use the chalk powder, like in step 2, again. Then, you must put a model in the middle of the case to create the feeder. This will be the hole, where you pour the liquid aluminium in later.

Fill the cope exactly like the drag, layer by layer.

Figure 7: Feeder of the mold

8.

Finally, you can pull out the model in the middle of the case carefully. Then, put the cope on the drag and stick the dowel pins in the holes on the sides of the cases to avoid moving. The feeder should be in the middle of the cavity, of the model you are going to cast, in the bottom half of the mold.

The preparation of the sand casting mold is finished, after you cleaned the place where you were working at.

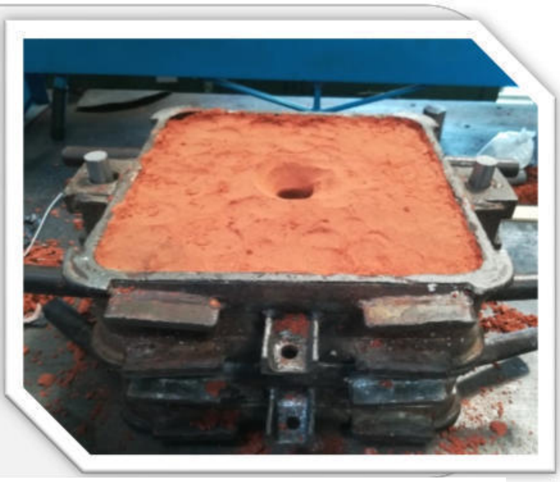


Figure 8: complete mold

9.

The next step is to heat the furnace and melt the aluminium you are going to cast with. Put the aluminium in the furnace, set the temperature of 805 °C and the timer on 300 minutes.

If the aluminium parts are too big for the furnace, ask one of your teachers and he will show you how to work with the saw in the laboratory.

Figure 9: Melting furnace

10.

As soon as the aluminium is molten, you can start the casting process. Place the mold in front of the furnace and tilt the furnace until the aluminium is getting poured into the hole.

Possibly, you must turn on the ventilation system.

Figure 10: Pouring of the aluminium

11.

At the next day, you can destroy the sand and take out the product. Take care, that you separate the sand. You must dispose the burned sand; the rest can be used again for the next sand casting process.

Figure 11: Final production

12.

Finally, you can cut off all the goodies/parts for tensile testing and grind them.

The tensile testing parts are going to be used by the Master students and the goodies are for you to keep them and open the one or the other bear.

Figure 12: Final sand casting goodie

In the following scheme presentation, you can see all the steps of the mold preparation again. Make sure, that you understood everything, before starting to work.

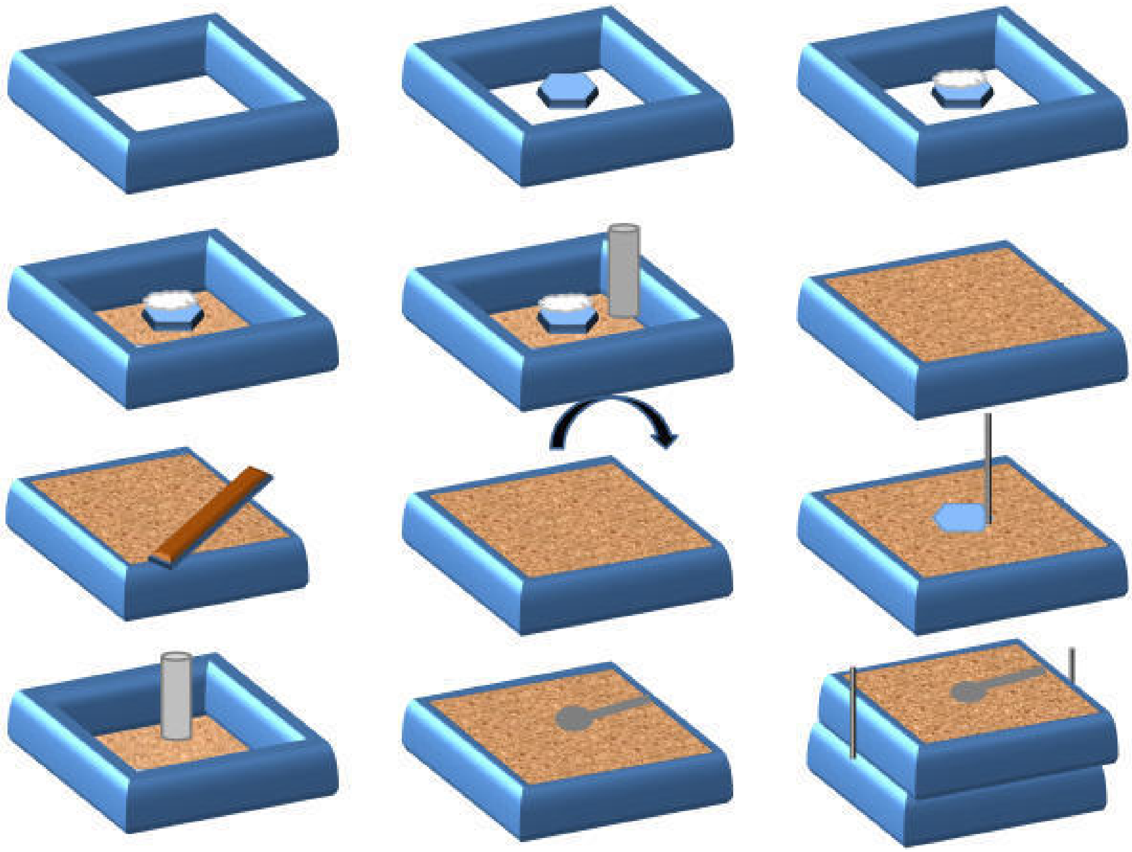


Figure 13: Sand casting scheme I

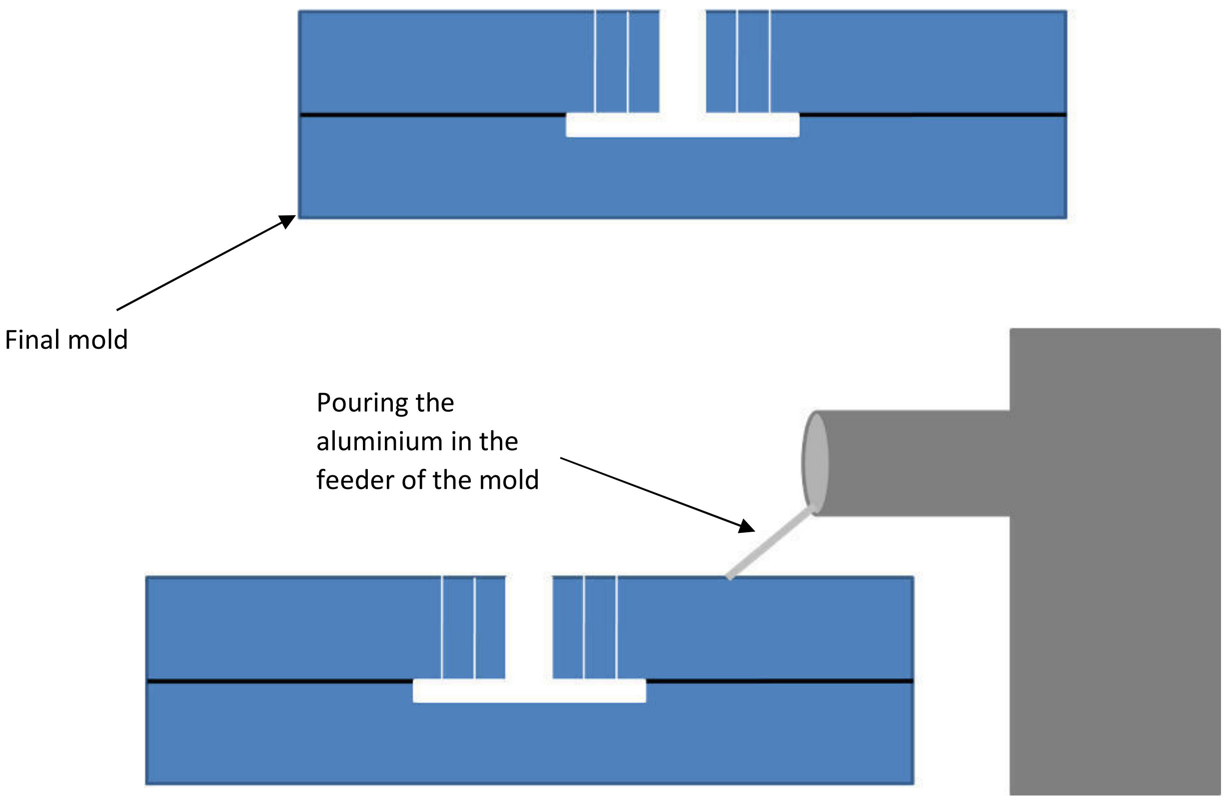


Figure 14: Sand casting scheme II

Lost wax handbook

4. Lost wax casting

4.1 Basic information

The lost wax process is a process with expandable mold, that means that in during the process the mold is getting destroyed at some point. It is used to cast very complex parts with metal or glass. It is called lost wax process, because to perform the process you need a model of the part you are going to cast made with wax. The mold is getting made around the wax model and after it is getting heated until the wax evaporates to get the mold. In the next steps, the casting process is getting performed. After the metal or glass solidified, the mold must get destroyed to get the final production. The lost wax process is known since 4th millennium B.C. And was usually used for tin and bronze. Today, for example the Radiator mascot of Rolls-Royce is getting casted with the lost wax process.

For the lost wax process, you will get a model printed in wax with a 3D-printer. The material is the MOLDAY filament. The MOLDLAY filament is developed for casting and becomes completely liquid at 270°C. It is a wax-like thermoplastic which can be used for printing a model to prepare a lost wax mold. Also, it features an excellent dimension stability and has almost no warping effect. At room temperature, the printed model remains stiff and rigid. The filament becomes liquid (with a thin oil viscosity) when heated up to about 270°C thanks to some specially chosen types of oily paraffin.

Material characteristics:

- designed for printing casting molds;
- dimension stability;
- stiff, rigid at room temperature;
- near zero warp;
- printing temp: between 170°-180°C;
- heated bed 20°C (max. 40°C), use capton tape + ABS paint, or HIPS bed or other, it sticks well;
- molds must be treated at approx. 270°C in a furnace;
- the wax flows restless out the mold, similar as hot paraffin.

4.2 Equipment

Before starting work, make sure you have all the tools you need. This will allow you to perform the process safely for you and other people in the lab.

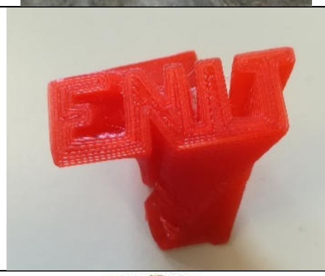
Plaster	
Tin can	
Model (printed in wax with a 3D-printer)	
Oil bound sand	
Protective clothing	  
Beater	

Table 2: Equipment for lost wax

4.3 Step-by-Step instructions

1.

The first step is to prepare the Plaster according to the instructions on the backside of the package. You should use about 3 tablespoons of powder for one model.

Figure 15: Plaster preparation

2.

Then dip the model in plaster and cover it completely. Make sure, that also all the wholes of the model are filled.

Figure 16: Covering the model with plaster

3.

Start filling the sand in the tin and press it firmly with the beater to create a first layer of sand. The process is the same as in the sand casting mold preparation part. Then place the, in plaster covered, model in the middle of the tin and fill it with sand up to the height of the upper surface of the model.

In the next step drill some holes for the feeders and the gas vents in the parts. Be very carefully and try to damage the surface of the wax model as less as possible

Figure 17: Drilling of the holes in the mold

4.

Place some candles or other cylindrical wax parts your teacher provides you with on the holes and keep on filling the tin with sand. The candles will form the feeder and the gas vents of the mold.

Figure 18: Place the candles

4.

After the mold preparation is finished, you need to put the mold in the furnace for 2 hours on 625°C. The wax in the mold will evaporate and you just the mold with a cavity of the model and the feeder/gas vents will remain.

Figure 19: Wax furnace

5.

The next step is to heat the other furnace and melt the aluminium you are going to cast with. Put the aluminium in the furnace, set the temperature of 805 °C and the timer on 300 minutes.

If the aluminium parts are too big for the furnace, ask one of your teachers and he will show you how to work with the saw in the laboratory.

Figure 20: Melting furnace

6.

If the aluminium is melted you can start the casting process. You should use a spoon to pour the aluminium in the feeder of the mold. It is not possible to pour it directly from the furnace, because it is not precise enough.

Figure 21: Lost wax casting

7.

After the aluminium solidified, you can destroy the sand mold and take out the product. After, destroy also the plaster around the part.

Figure 22: Final production

8.

The last step, is to cut the feeders off the part and grind it to contain the goodie finally.

Figure 23: Final lost wax goodie

In the following scheme presentation, you can see all the steps of the lost wax process again. Make sure, that you understood everything, before starting to work.

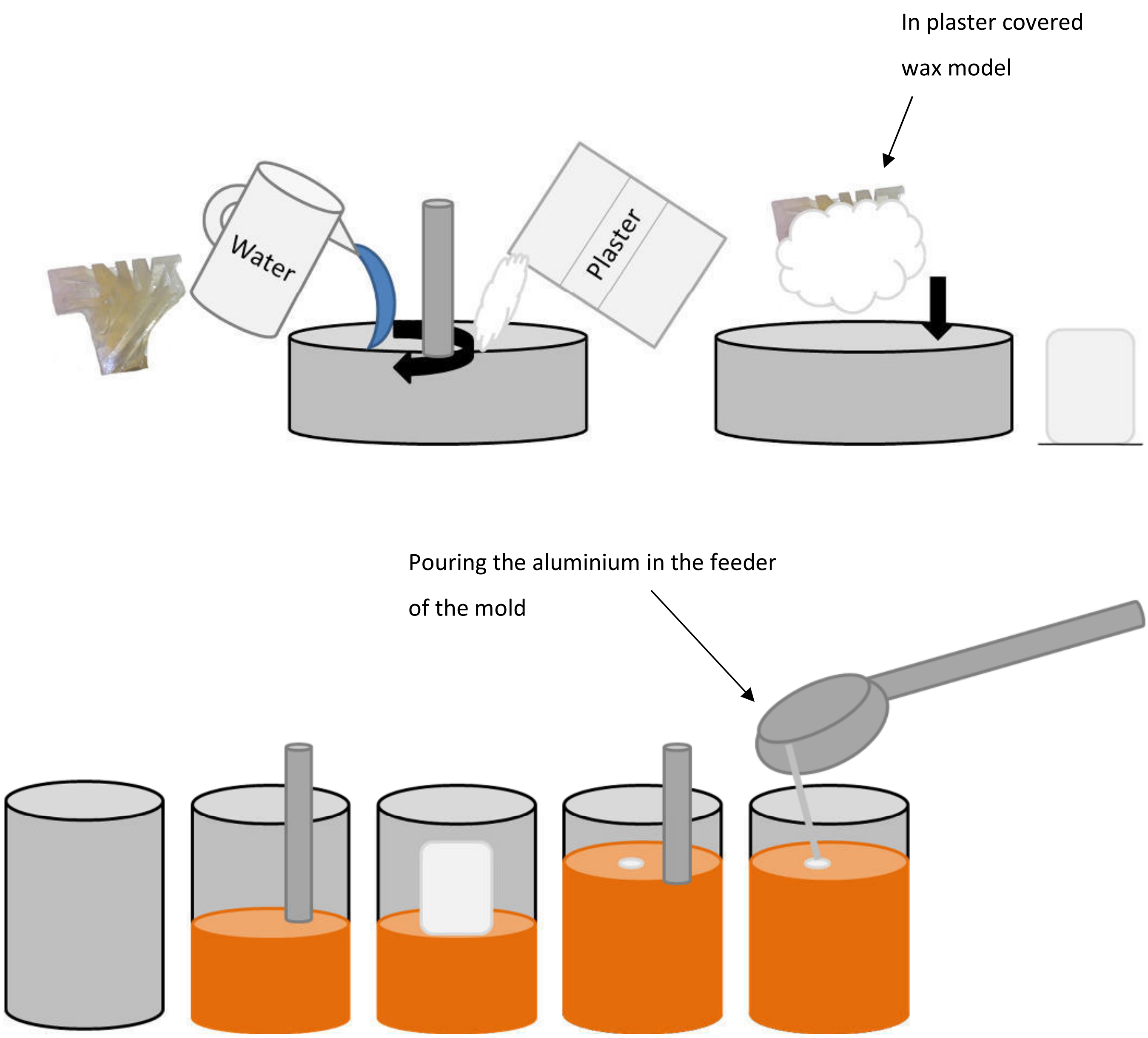


Figure 24: Lost wax scheme

5. List of Figures

6. List of tables

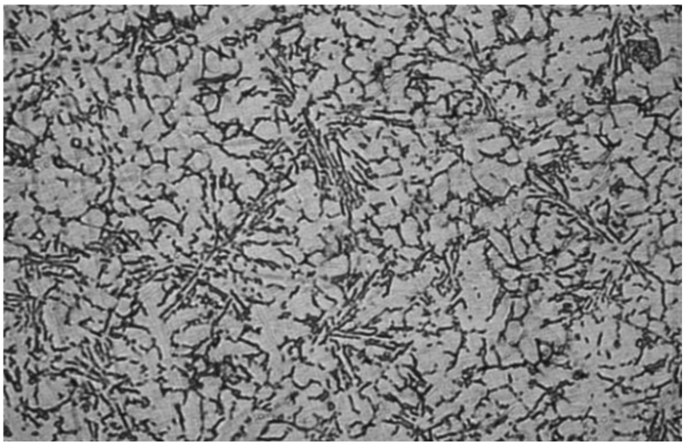
Appendix 5

Master Handbook

The fifth part of the appendix is the Master Handbook, besides the Bachelor Handbook our main deliverable. The Master Handbook is about metallographic examination of parts Bachelor students cast before.

Master Handbook

Metallographic Examination



Content of the handbook

1. Introduction and safety

The Master handbook was developed for both the theoretical knowledge and the practical part of practical work in the laboratory. It is based on the knowledge and experience gained by the 5-person group of students of the European Project Semester. We hope that our knowledge gained during the experiments will allow you to learn effectively.

A special thank goes to our technical supervisors Francois Grizet, Yannick Balcaen and Guillaume Mazenc, as well as our management supervisor Philippe Fillatreau for their advice and guidance on the project. We would not be able to complete the project without them.
We would also want to express our greatest gratitude to all the teachers and colleagues from the EPS for all their help and support during this months.

Before you can go to the laboratory and start casting, it is mandatory to read the whole Handbook.

Safety Rules

- Always wear the protection clothes you get provided with by your teachers
- Keep Emergency exits easily accessible
- Report unsafe conditions to your teacher
- Be aware of your surroundings
- Do not run in the laboratory
- Use tools and machines properly
- Be always concentrated and take a break if necessary

2. Structure of the handbook

The Master Handbook consists of one part. There is metallographic examination for tensile test part. This part will contain theoretical knowledge about the process and explain how to perform it step by step. The Master Handbook is designed for master students and it will take a time of about two hours. With the metallurgical test process, you will prepare a sample for metallographic examination and analyse the results.

We have 1 day for all stages of metallographic examination.

Day 1: For the whole process, you will need about two hours. In the beginning, all master students cut the sample in 2 directions. After they obtain the cut parts, students mold them. After the molding process is complete, the molded parts will be grinded. After each stage of the grinding process has been successfully completed, polishing and etching processes will be performed. Then, the sample preparation process is completed, the prepared sample will be examined under the microscope.

Finally, you will see images of the sample while examining the samples at the microscope and you will analyse the images with your teacher.

Metallographic Examination

3. Metallographic examination

3.1 Basic information

The metallographic examination process analyses the internal structure of the materials and gives information about the properties of the material. This method is very important in the quality control process. It shows which processes the materials have gone through, the defects and errors in the internal structure of the material, the properties possessed by the material, and what can be done to change these properties. At the same time, information about the life of the material can be obtained with this examination. This process is usually applied to metal materials.

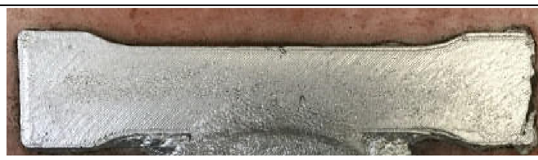
This examination consists of specific stages. The first step is **sampling**. To obtain a good result at the end of the examination, the sample should be taken transversally and longitudinally from the part. A rotary disc cutting device is usually used for sampling stage. Second step is **molding**. After the part to be examined has been cut, the part is molded for easier grinding and examining. Basically, two different moldings are made.

- Hot molding; Powder materials with plastic properties are generally used for this molding type. After the suitable material for molding is selected, the molding material is placed with the sample on the automatically operating molding device. Due to the effect of pressure and temperature, the molding material fuses perfectly to form mold around the sample.
- Cold molding; This molding process is carried out entirely at room temperature and there is no external pressure or temperature effect. Resin and hardener are used in cold molding process. Put the samples, resin and hardener into the cabinet where the mold is to be formed and wait for the mold to solidify.

Third step is **grinding** and **polishing**. The molted samples must have a smooth surface to obtain good results when examining under the microscope. This process is carried out in the grinding device and abrasive papers containing SiC are used for grinding. The main purpose of polishing is to obtain a surface that reflects the light well. Polishing is done by abrading the grinded surface with abrasive particles applied onto the fabric on a rotating disk. A kind of lubricant is also used to reduce friction. When polishing is finished, the surface of the sample is similar like a mirror. Fourth step is **etching**. After the surface smoothness is obtained, the material is subjected to etching treatment. This process is applied to make the microstructure of the material visible under the microscope. The etching process is generally carried out by reacting the material surface with chemical solutions. The solutions are obtained from mixtures of materials such as alcohol, pure water, glycerine, acid, according to the sample material. This process is applied by immersing the sample in the solution prepared for the material and after waiting for a certain period, then cleaning the surface of the sample with alcohol or water and drying the face. The waiting time depends on the type of material. In this process, the solution prepared and the etching time affect us to obtain a successful result. The last step is to **examine with a microscope**. The prepared sample is examined with a microscope and information related to the internal structure of the material is obtained.

3.2 Equipment

Before starting work, make sure you have all the tools you need. This will allow you to perform the process safely for you and other people in the lab.

Tensile test part	
Rotary disc cutting device	
Resin & hardener for molding (Poudre Plexcil A6 and Catalyseur Plexcil C6)	
Molding case & tools	
Polishing papers & lubricants	

Grinding & polishing machine	
Abrasive papers	
Optical microscope	
Protective clothes	

Table 1: Equipment for metallographic examination

3.3 Step-by-Step examination

Here you have step by step instructions to prepare the sample for metallographic examination.

1.

For the first step, you need to cut the tensile test part in 2 directions. One of them is from center of the part and the other is from top of the part. You will use rotary disc cutting device for cutting process.

Figure 1: Cut parts

2.

After obtaining 2 specimens, you will mold them. For the molding process, you will put the cut specimens such the surface to be examined of the parts will touch the bottom base of the mold.

Figure 2: Parts placed in the mold

3.

After placing the specimen, mix Poudre Plexcil A6 and Catalyseur Plexcil C6 in another bowl. It will suffice to use about 125 ml of both. After the 2 ingredients are mixed enough, fill the mixture with the ingredients in the mold.

Figure 3: Molding case and tools

4.

Allow the mixture to solidify for 15 minutes and remove it from the mold.

Figure 4: Mold and molted sample

5.

Once you have your molded parts ready, proceed to grinding. In the grinding process, you will use abrasive papers respectively P80, P320, P600, P1000 and P4000. Use the grinding machine at high speed and with water clear. Do not forget to clean the surface of the machine with water every time you change the paper!

Figure 5: Abrasive papers

6.

Make sure that the scratches on the surface of the material are parallel to each other during the grinding process. After use the all abrasive papers, clean surface of the specimen with water.

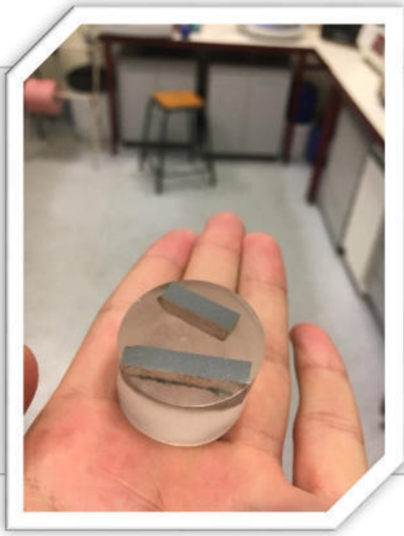


Figure 6: Grinded sample

7.

After the grinding process is complete, proceed to polishing. You will use the same machine for grinding and polishing. You will use respectively 3 µm and 1 µm papers. You will use 3 µm diamond suspension for 3 µm paper and 1 µm for 1 µm paper. Continue polishing until the surface is as bright as a mirror.

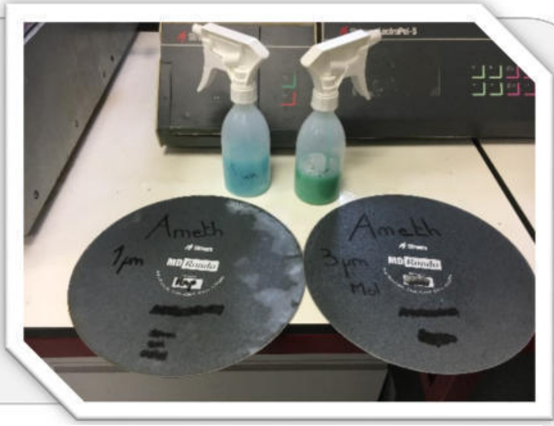


Figure 7: Polishing papers and lubricants

8.

After obtaining a bright surface as desired, you will examine the sample under the optical microscope. If you can see the silicon in between the grain boundaries, do not need to do the etching process.


Figure 8: Optical microscope

9.

Finally, you need to obtain a similar image like the figures. If you have obtained these results, you will take some pictures. After then, discuss the results with your teacher.

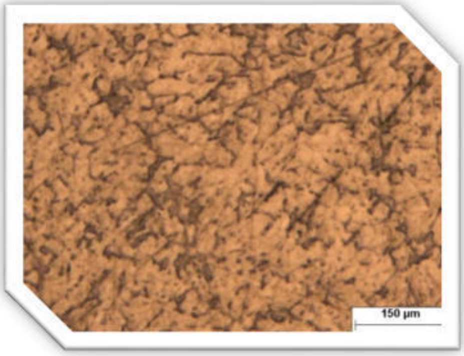


Figure 9: Microstructure of the sample (center of the part)

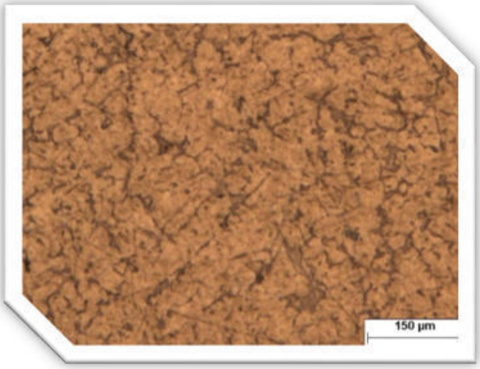


Figure 10: Microstructure of the sample (top of the part)

4. List of figures

5. List of tables

Appendix 6

Training steps

The chapter Training steps is about all the things we needed to learn to reach the aim of the project. It is divided in the topics CATIA, Repetier-Host, Microsoft Project and Casting.

Training steps

1. CATIA

CATIA V5 is a computer aided design (CAD) software used to create technical parts and assemblies that are accurate, it is considered as the best software for technical parts' design.

We decided with our technical supervisors that everyone should learn how to use CATIA because we thought it would be beneficial for our knowledge. We allowed one week for training because none of the team members had any prior experience using this programme, at least three of us had knowledge about SolidWorks which is a similar program but some commands are different in this software.

We went to a training class during the first week of the project for learning the first steps about CATIA. It gave us a basic idea on how to use the program and showed us how to use different techniques to design parts that can be difficult to create.

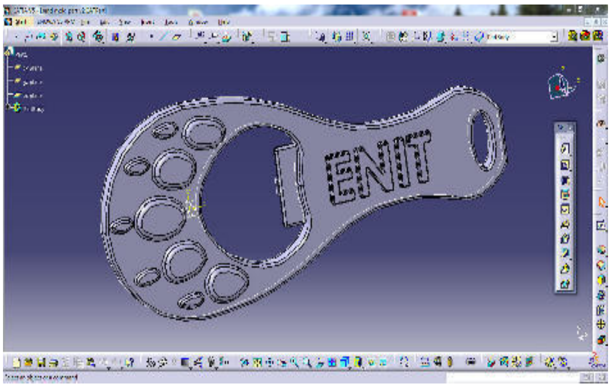


Figure 1: An example from CAD designs

The training in CATIA was important so that we can appreciate the difficulties that may occur when designing parts in the software and how to solve them. We learned the basic tips about this software, but when we need help, our supervisors always helped us. When our project was completed, each group member learned basic information about CATIA.

2. Repetier-Host

This is the program used to generate the codes needed to manage the movements 3D printer uses when producing a part, this code is known as gcode. The aim of this program is to make the connection between the CAD file of the part and the printing of it.

We use the ENIT computers available in the EniOne room to use this software because they are actually set with all the parameters needed for printing, the process for obtaining the gcode is quite easy. We trained for one day how to use this software and all the 3D printers available in our office.

Those are the parts we printed the first day just for training:

Figure 2: First printed test parts

Finally, you can find simulations of some of the parts that are created using this program below Repetier-Host with the design of the sand mold goodie and also there is a sample of the gcode.

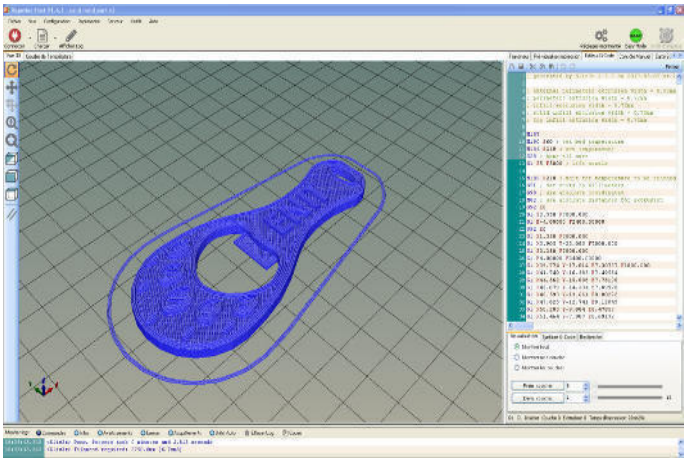


Figure 4: Sand casting goodie design at Repetier-Host

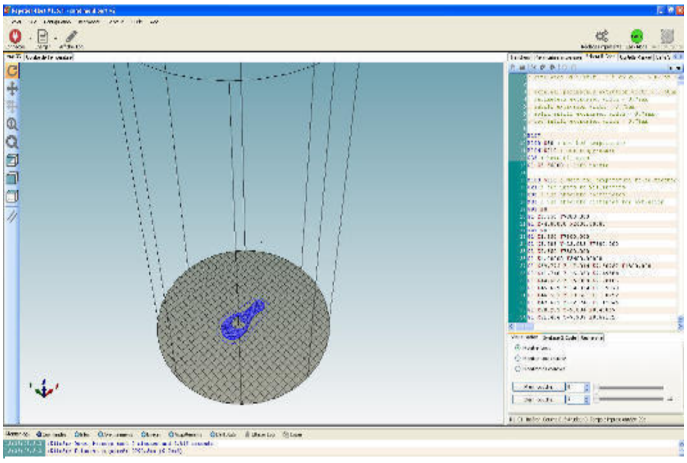


Figure 5: Sand casting goodie design at Repetier-Host

```
; generated by Slic3r 1.2.9 on 2017-05-02 at 15:41:05

; external perimeters extrusion width = 0.50mm
; perimeters extrusion width = 0.72mm
; infill extrusion width = 0.72mm
; solid infill extrusion width = 0.72mm
; top infill extrusion width = 0.72mm

M107
M190 S60 ; set bed temperature
M104 S210 ; set temperature
G28 ; home all axes
G1 Z5 F5000 ; lift nozzle

M109 S210 ; wait for temperature to be reached
G21 ; set units to millimeters
G90 ; use absolute coordinates
M82 ; use absolute distances for extrusion
G92 E0
G1 Z0.350 F7800.000
G1 E-4.00000 F2400.00000
G92 E0
G1 Z1.350 F7800.000
G1 X3.905 Y-23.083 F7800.000
G1 Z0.350 F7800.000
G1 E4.00000 F2400.00000
G1 X39.774 Y-17.014 E7.30787 F1800.000
G1 X41.740 Y-16.383 E7.49564
G1 X44.562 Y-15.008 E7.78106
G1 X45.679 Y-14.334 E7.89970
G1 X46.593 Y-13.661 E8.00292
G1 X47.623 Y-12.741 E8.12845
G1 X50.203 Y-9.884 E8.47857
G1 X51.464 Y-7.907 E8.69172
G1 X51.519 Y-7.778 E8.70449
G1 X52.038 Y-5.910 E8.88083
G1 X52.115 Y-4.855 E8.97698
G1 X52.115 Y4.855 E9.85989
G1 X51.821 Y6.899 E10.04767
G1 X51.763 Y7.097 E10.06645
G1 X50.460 Y9.592 E10.32238
G1 X48.972 Y11.441 E10.53820
G1 X47.958 Y12.471 E10.66958
G1 X46.091 Y14.020 E10.89022
G1 X44.640 Y14.956 E11.04722
G1 X41.669 Y16.405 E11.34776
G1 X39.703 Y17.036 E11.53548
G1 X-12.932 Y25.959 E16.38990
G1 X-18.166 Y26.668 E16.87019
```

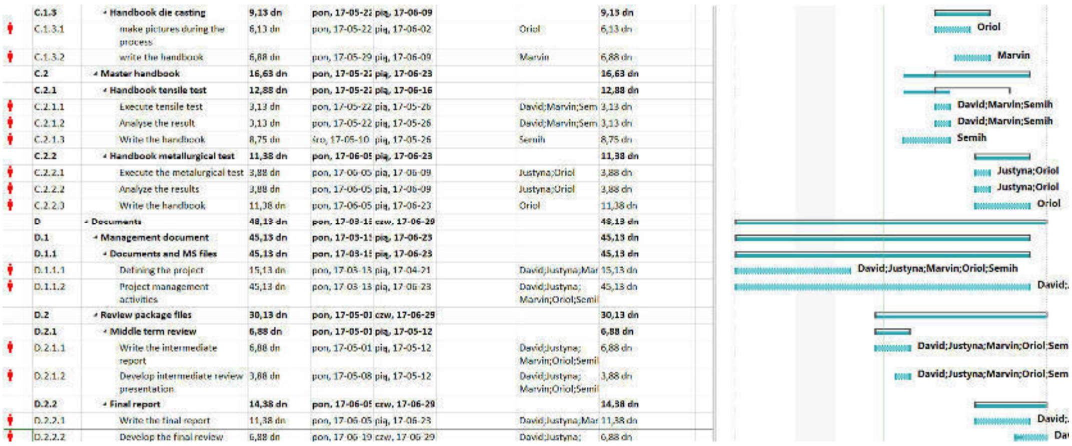
Figure 3: An example gcode

Through these training, we have learned the principles of operation of the 3D printer. When we had a problem with the program and the 3D printer, our supervisors always helped to us. When the project was completed, each group member learned basic information about Repetier Host.

3. Microsoft Project

During the semester, we have done eight hours of training on Microsoft Project, meaning that each team members understand how the software works. This is beneficial for the whole team because even if it is not your task to work on the software, you can still understand the different steps done and help with monitoring if someone is too busy. During the training, we followed an artificial project that required us to set up:

- Tasks
- Milestones
- Costs
- Workload
- Duration
- Predecessors
- Planning & Monitoring
- GANTT chart



C.1.3	Handbook die casting	9,13 dn	pon, 17-05-22	pią, 17-06-09		9,13 dn
C.1.3.1	make pictures during the process	6,13 dn	pon, 17-05-22	pią, 17-06-02	Oriol	6,13 dn
C.1.3.2	write the handbook	6,88 dn	pon, 17-05-29	pią, 17-06-09	Marvin	6,88 dn
C.2	Master handbook	16,63 dn	pon, 17-05-22	pią, 17-06-23		16,63 dn
C.2.1	Handbook tensile test	12,88 dn	pon, 17-05-22	pią, 17-06-16		12,88 dn
C.2.1.1	Execute tensile test	3,13 dn	pon, 17-05-22	pią, 17-05-26	David;Marvin;Sem	3,13 dn
C.2.1.2	Analyse the result	3,13 dn	pon, 17-05-22	pią, 17-05-26	David;Marvin;Sem	3,13 dn
C.2.1.3	Write the handbook	8,75 dn	śro, 17-05-10	pią, 17-05-26	Semih	8,75 dn
C.2.2	Handbook metallurgical test	11,38 dn	pon, 17-06-05	pią, 17-06-23		11,38 dn
C.2.2.1	Execute the metalurgical test	3,88 dn	pon, 17-06-05	pią, 17-06-09	Justyna;Oriol	3,88 dn
C.2.2.2	Analyze the results	3,88 dn	pon, 17-06-05	pią, 17-06-09	Justyna;Oriol	3,88 dn
C.2.2.3	Write the handbook	11,38 dn	pon, 17-06-05	pią, 17-06-23	Oriol	11,38 dn
D	Documents	48,13 dn	pon, 17-03-13	czw, 17-06-29		48,13 dn
D.1	Management document	45,13 dn	pon, 17-03-13	pią, 17-06-23		45,13 dn
D.1.1	Documents and MS files	45,13 dn	pon, 17-03-13	pią, 17-06-23		45,13 dn
D.1.1.1	Defining the project	15,13 dn	pon, 17-03-13	pią, 17-04-21	David;Justyna;Mar	15,13 dn
D.1.1.2	Project management activities	45,13 dn	pon, 17-03-13	pią, 17-06-23	David;Justyna; Marvin;Oriol;Semi	45,13 dn
D.2	Review package files	30,13 dn	pon, 17-05-01	czw, 17-06-29		30,13 dn
D.2.1	Middle term review	6,88 dn	pon, 17-05-01	pią, 17-05-12		6,88 dn
D.2.1.1	Write the intermediate report	6,88 dn	pon, 17-05-01	pią, 17-05-12	David;Justyna; Marvin;Oriol;Semi	6,88 dn
D.2.1.2	Develop intermediate review presentation	3,88 dn	pon, 17-05-08	pią, 17-05-12	David;Justyna; Marvin;Oriol;Semi	3,88 dn
D.2.2	Final report	14,38 dn	pon, 17-06-05	czw, 17-06-29		14,38 dn
D.2.2.1	Write the final report	11,38 dn	pon, 17-06-05	pią, 17-06-23	David;Justyna;Mar	11,38 dn
D.2.2.2	Develop the final review	6,88 dn	pon, 17-06-19	czw, 17-06-29	David;Justyna;	6,88 dn

Figure 6: Screenshot for training in Microsoft Project

4. Casting

Firstly, we had to try all the casting methods in the bachelor's handbook. For this purpose, we have casted 3 times. We did the first one with the other ENIT students who are working about the casting. The other two are for our own project. Casting method basically consists of 2 steps. These are mold preparing and casting.

4.1. Mold Preparing

We first prepared the 3D model of the part what we will produce for sand mold casting and lost wax casting. In the beginning, we designed the models together with the feeders in the CATIA program. In the figure, you see the design of the tensile test sample which we will cast in sand mold.

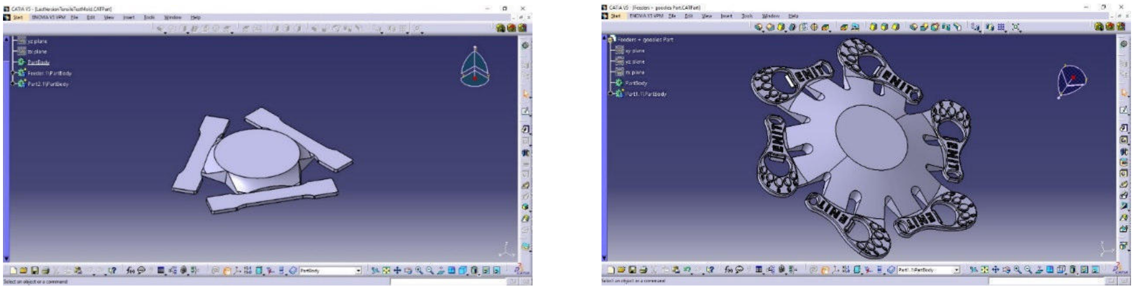


Figure 7: Designs of the models for sand mold

After we designed the model, we printed it on 3D printers. In the direction of our need, we have printed various models and used them in mold preparing. After the models were printed on the, we made sand mold.

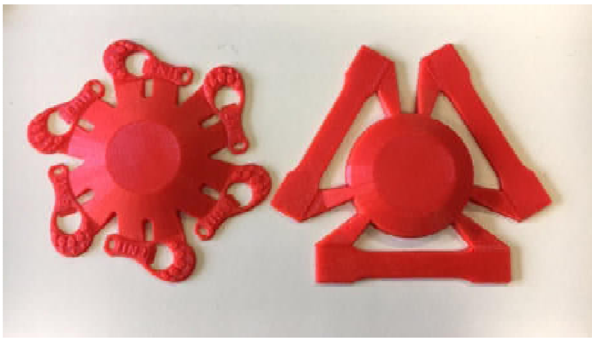


Figure 8: Models for preparing sand mold

While preparing the mold, we prepared the part where the model was at first and then the part where the metal is pouring. After we prepared 2 parts, we put them together and fixed them with pins.

Figure 9: Mold preparation

The mold for the lost wax casting method is different. In the beginning, we have designed a complex-shaped part because lost wax casting is one of the most suitable methods for producing complex shaped parts. We decided to use a part of ENIT on one side and INTP on another side with the recommendation of our supervisors.

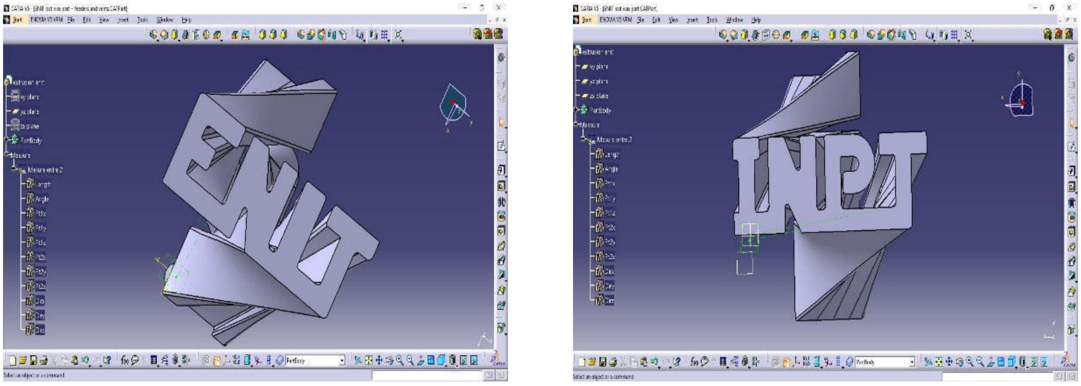


Figure 10: Model design for lost wax casting process

After we designed the model for lost wax casting, we printed in wax it on 3D printers and we prepared the mold for casting. We used plaster, sand and candle for preparing mold. First, we covered the wax model with plaster. After the covering process was completed, we placed the candles and covered all the parts with sand.

Figure 11: Lost wax mold preparation steps

After the mold was completed, we put the mold in a furnace at 625°C to evaporate the candles and the wax model and waited for about 2 hours.

4.2. Casting

After all the molds were prepared, we performed the casting process. We used aluminum alloy which include %6 silicon for casting. We put the metal in melting furnace set the furnace to 805°C and waited about 5 hours to warm up and melt the metal. After about 6 hours, the aluminum became ready for pouring.

Figure 13: Melted metal in the furnace

Figure 12: Poured metal in the sand mold

After casting the sand mold, we poured the metal to the lost wax mold with casting spoon.

Figure 14: Casting process for lost wax mold

List of figures

Appendix 7

Design steps

The section, design steps, is about all the CAD designs we have created during the project. In the beginning, we explained the lost wax design. After, the design of the sand casting goodie and the testing parts with some calculations of both. And finally, the biggest part of this section is about the die casting mold with the explanation of the design and some calculations we made.

Design steps

1. Introduction

The aim of the project is it to create practical lessons for students to teach them three different casting processes. The supervisors wanted to let the students cast a goodie with the lost wax process and 12 goodies with the sand casting process. Also, they should cast three parts to perform a tensile test and metallurgical tests with the sand casting and the die casting process.

According to this situation we had to design three different parts with the software CATIA. We must design the two different goodies, the parts for the testing part, which takes part in the practical lesson for master students, and, we must develop the molds for the processes. For the goodies, we carried out a brainstorming to decide how they will look like.

In the following sections, we will explain our first ideas and their evolution over the course of the project.

2. Lost wax goodie:

The Design of the goodie for the lost wax process should be very complex. It should have a shape, which is not be able to cast with another process. Also, it supposed to be representative for the ENIT. After the casting process, the clients of the project will decide what they are going to do with the goodie. It could be used as a giveaway or eye-catcher in the office of the teachers of the ENIT.

With the first brainstorming, we developed the idea of casting a popular place of the Pyrenees. We were thinking a shape, which looks like the Cirque du Gavarnie (Figure 1). There are some web pages, where it is possible to generate a CAD model for some places of the Pyrenees and other spots. This model should also include a ENIT logo somewhere.

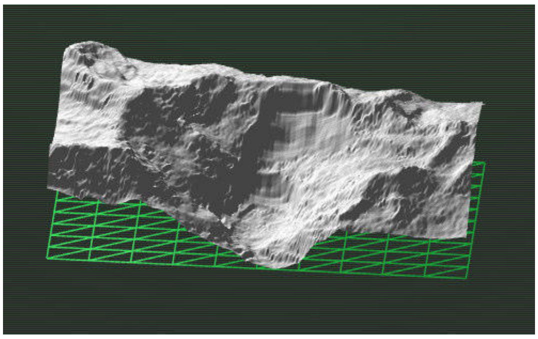


Figure 1: Lost wax goodie - Cirque du Gavarnie

For us it was a good idea, but no member of our group was totally happy with this idea. Also, it was not possible to print it with a 3D-printer accurate enough. In a meeting with our supervisors, we decided together, that we could use another goodie.

The idea was to use a spiral of the ENIT logo and the INPT logo on the other side (Figure 2 & 3). We must make clear, that the design was already made by one of our technical supervisors. But we decided to choose it, because it is a perfect example for the lost wax process. It has a very complex and difficult shape. So, there is no other casting process, which can cast a part like our chosen Goodie. We got the CAD design of our goodie from one of our technical supervisors and I was also printed already. To make the final decision we had to test, if it is possible to print the goodie in wax (Figure 4 & 5). After we succeed we finally decided, that we will use the goodie for the lost wax process.

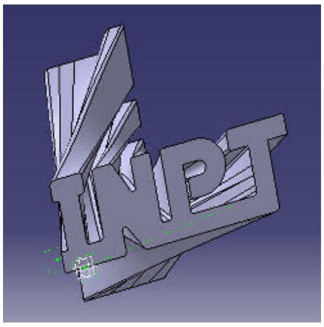


Figure 2: Lost wax goodie CAD II

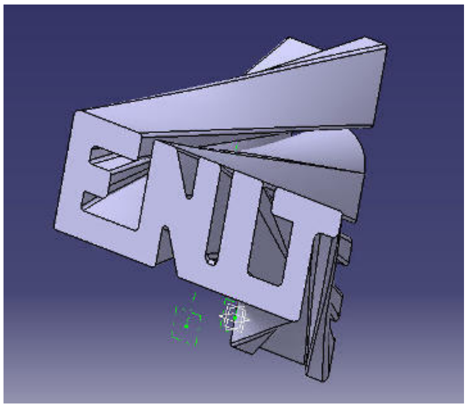


Figure 3: Lost wax goodie CAD II

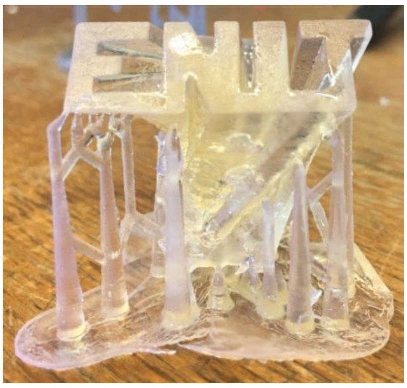


Figure 5: Lost wax goodie 3D printed in wax I

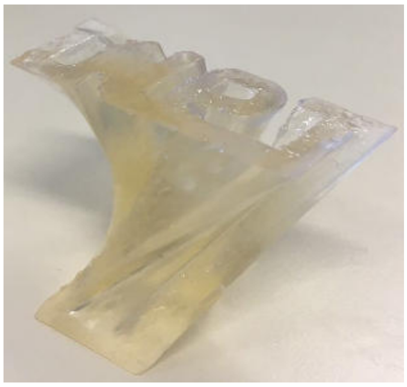


Figure 4: Lost wax goodie 3D printed in wax II

The next step was to perform the casting process. We prepared the molds and casted two Goodies and a Darth Vader (Figure 6). After the process, we can say, it was successful. Even if the parts do not look perfect, we did not even know if we could fill the mold before. While the process, we learned that a candle is not the best wax part to create a feeder. The best option in our opinion would be to print the

Figure 6: Lost wax production

feeders together with the goodie. The problem about this solution is, that the wax is very expensive. There are some tried necessary to find the optimal solution. Also, we used two different kinds of wax and recognized that the goodie printed with a filament of wax is better for the lost wax process than the goodie printed with resin. After we compared our results with the results of another group of students, who tried the lost wax process, we can say that the plaster also has a big impact on the quality of the casting. In our case, we did not use a plaster which is especially for lost wax casting. We are sure that the results will be way better with a proper plaster to prepare the mold.

3. Sand casting

The aim of the sand casting process was to produce two different kinds of parts. First, the 12 goodies to keep for the students and second, three parts for the master students to perform a tensile test and metallurgical tests in their practical session.

3.1. Sand casting goodie

This goodie should be interesting for students, because one of the aim of this project is making casting classes enjoyable for ENIT students so considered this topic and decide the goodie. In the sand casting process, the students should cast 12 goodies, so every student can keep one for himself. We wanted to design a goodie, which is useful for the students and reminds them about the ENIT. We decided to create a beer opener like a bear claw. The shape of a bear claw, was chosen for this goodie, because it is a symbol of Tarbes. We started to design the goodie in CAD, printed it and improved it several times, after trying to open a bottle or cast it. The goodie broke very easy, while trying to open a bottle, but we still got some important information to further develop the goodie. Here you can see the evolution of the process (Figure 7).

The biggest Changes we made in the beginning were about the hole and the thickness of the goodie. In the beginning, it was not possible to open a bear, because of the shape of the hole. Also, the thickness of the goodie was a problem. If it is too thick, it is not possible anymore to open a beer. If It is to thin, it is not stable enough and not possible to cast. Another point we realized was, that the surface of the 3d printed models are not very smooth and accurate. For testing the casting process is it enough, but our supervisors will manufacture the models with a milling machine to improve the quality of the products.

Figure 7: lost wax goodie evolution

After we tried to prepare the first mold, we made some other improvements (Figure 8). We made the holes bigger and changed the shape of the letters. Also, we changed the square in the hole to make the beer opening process easier. Finally, we casted our goodie for the first time and succeeded. The sand casting process worked good and the beer opener did as well. We decided to try some different positions of the goodies and the feeders and designed them also in CAD and printed them to improve the process of the sand mold preparation (Figure 9). After the CAD design was created, we proved if the model works properly with calculating the flow rate, the velocity of the melted aluminum and the use of Chvorinov´s rule.

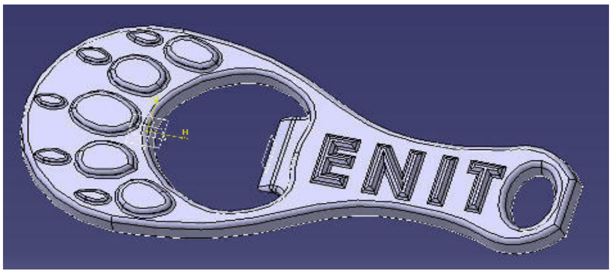


Figure 8: sand casting goodie CAD

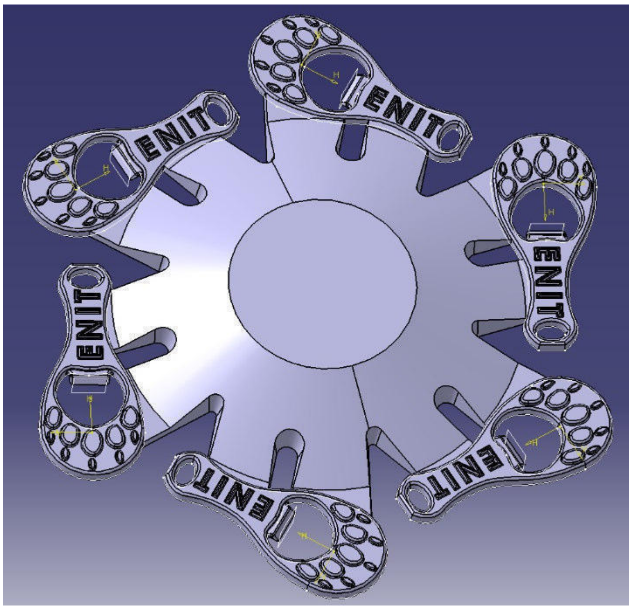


Figure 9: sand casting model for goodies CAD

3.2. Sand casting testing parts

The design of the tensile test sample is quite easy because the dimensions are regulated so the only thing we had to do is to calculate it and create the CAD design.

On the right, you can see the basically design of the parts we will use (Figure 10). We used the following values and formulas to calculate the dimensions of the parts.

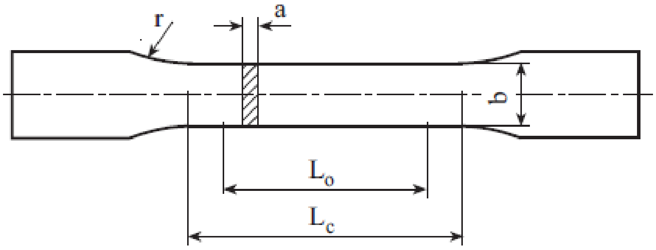


Figure 10: Testing part scetch

a = 5 mm (We could choose it on our own.)

b = 25 mm

$$L_0 = 5{,}65 * \sqrt{S_0} = 5{,}65 * \sqrt{25\,mm * 5\,mm} = 63\,mm$$

Equation 1: Measure zone of testing part

L_0 is the zone, where we will measure the strain of the part. It is possible to round off L_0, so we decided to use 60 mm.

S_0 is the area of the part in the testing zone.

$$L_c = L_0 + 2 * \sqrt{S_0} = 60\,mm + 2 * \sqrt{25\,mm * 5\,mm} = 82\,mm$$

Equation 2: Length of the testing part

r = 25 mm

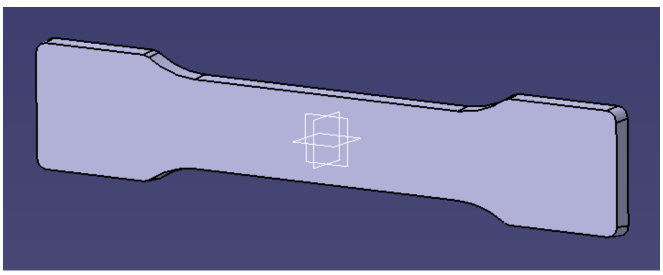


Figure 11: Testing part CAD

The dimensions of the end of the part are not important. It is just to hold the part with the tensile testing machine. First, we gave them a bright of 35 mm and a length of 20 mm. But after the first cast, we realized it is too small, so we increased the length on 35 mm. Also, we provided the part with five-degree angle to pull it out of the mold easier (Figure 11).

After we designed the Tensile test part in CAD, we printed it and prepared the mold and made the feeders with a normal spoon. To make the process easier, we also to print the feeders like we did for the goodie.

The plan was to position the feeders at the end of the tensile test parts to make sure, that the testing area is not getting damaged by cutting the parts off the mold (Figure 12). In the first try of casting with this design, the aluminum solidified too fast and the parts did not get filled. We realized that the feeders are too small and improved the design. Unfortunately, we had to place the feeders in the middle of the middle of the part to make sure, that the parts are getting filled properly (Figure 13). Also, we increased the size of the feeders. Unfortunately, we were not able to try the new design, because the furnace was broken.

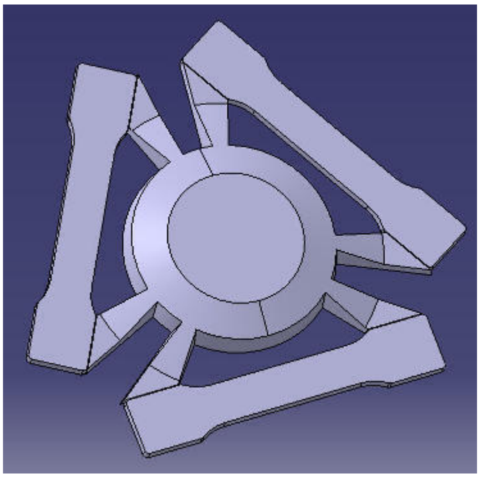


Figure 12: Testing part model I

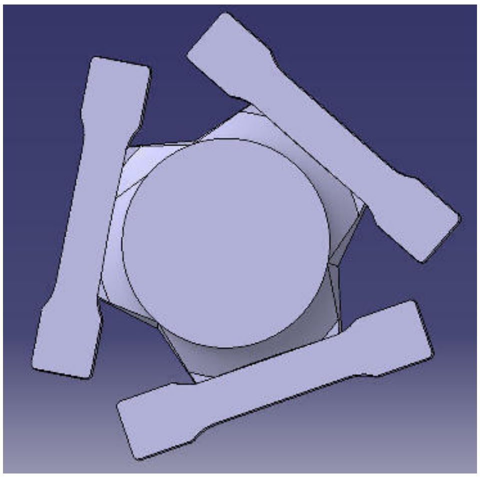


Figure 13: Testing part model II

3.3. Sand casting calculations

We calculated if the mold works with the flow rate, the velocity of the melted aluminum and the use of Chvorinov's rule. We prepared an excel file, which makes it possible to change all the variables to calculate a different mold automatically. In the following, you can see an example calculation for the goodie.

3.3.1. Flow rate

The flow rate is already defined; it will be determinate by the volume of melted metal used during the casting process and the time used for pouring it into the mould.

$$Q[m^3/s] = \frac{V[m^3]}{t[s]}$$

Equation 3: Flow rate defined by the volume and the time of pouring

It's possible to define those variables according the experience acquired at previous casting tests.

An approximate volume of the material used (Aluminium 413) is one litre.

Revising the videos made at previous cast we can define a time need for pour the aluminium properly, and at least ten seconds are required.

$$V[m^3/s] = 1[l] \cdot \frac{0{,}001\ [m^3]}{1[l]} = 0{,}001\ [m^3]$$

Equation 4: Volume of aluminium poured in m³

$$Q[m^3/s] = \frac{0{,}001[m^3]}{10[s]} = 0{,}0001[m^3/s]$$

Equation 5: Estimated flow rate for the pouring

3.3.2. Volume of the parts cavities and the runners and gates

According to the CAD design in CATIA the total volume of the parts and the runners is 242636,297 mm^3

$$V_{parts} = 242636{,}297[mm^3] \cdot \frac{1 \cdot 10^9[m^3]}{1[mm^3]} = 0{,}000242636297[m^3]$$

Equation 6: Volume of the parts and runners in m³

Knowing the volume that is needed to be filled and the flow rate already defined it's possible to define the time that will take to fill the cavities.

$$t[s] = \frac{V[m^3]}{Q[m^3/s]} = \frac{0,000242636[m^3]}{0,0001[m^3/s]} = 2,4263[s]$$

Equation 7: Time required to fill the parts and feeder's cavities

The rest of the time and volume of aluminium will be required for fill the feeder.

3.3.3. Calulate the velocity of the melted aluminium at the feeders base

The height of the feeder is already defined by the mould supports.

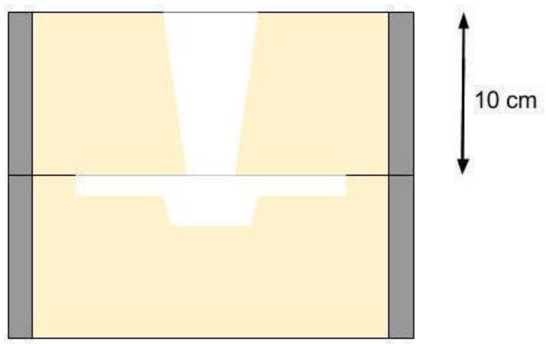


Figure 14: Diagram of the sand mold

The height of a half of the mold is 10 centimetres. Therefore, the feeder can have a maximum height of 10 cm.

For calculate the velocity at the base of the sprue, Bernoulli equation should be used. The Bernoulli equation is applied between the top of the sprue and the base.

$$h_1 + \frac{{v_1}^2}{2g} + \frac{P_1}{\gamma} = h_2 + \frac{{v_2}^2}{2g} + \frac{P_2}{\gamma}$$

Equation 8: Bernoulli equation betweet two points

We consider that P1 = P2 and is equal to the atmospheric pressure and v_1 negligible if it is compared it with v_2.

The velocity at the base of the sprue is defined by this equation;

$$v[m/s] = \sqrt{h[m] \cdot 2 \cdot g[m/s^2]}$$

Equation 9: Velocity of the base of the sprue

The velocity at the base of a sprue for a height of ten centimetres is;

$$v[m/s] = \sqrt{0{,}1[m] \cdot 2 \cdot g\left[\frac{m}{s^2}\right]} = 1{,}96[m/s]$$

Equation 10: Velocity of the melted metal for a height of ten centimeters

3.3.4. Calculate the feeders dimensions

A common design for pouring sprue is the following one

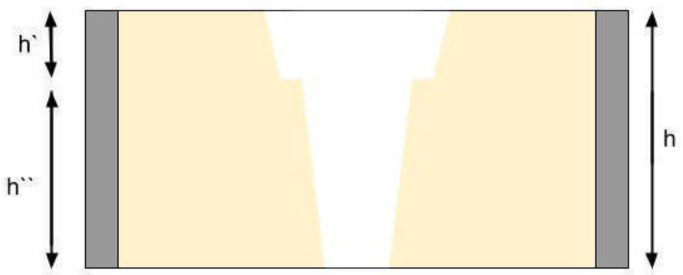


Figure 15: Sprue cup design

At the top is built a bigger cone with the aim of making the pouring easier.

We can delimit an approximate depth of 3 centimetres. (its defined that the height of the pouring cup should be 2,5 times the maximum diameter of the sprue, to avoid turbulences, as the maximum height of all the feeding system can be only 10 cm is not possible to apply this rule and have the flow rate already defined).

Applying Bernoulli equation for this height, the velocity of the melted metal at this point, and the diameter of the sprue cone at that point are defined.

Knowing the diameter of the cone at the base and in the top, we can define the dimensions, of the sprue.

According to the velocity of the melted metal at the base of the sprue the smallest diameter of the cone will be;

$$A[m^2] = \frac{Q[m^3/s]}{V[m/s]} = \frac{0{,}0001[m^3/s]}{1{,}96[m/s]} = 0{,}000510204\ [m^2]$$

Equation 11: Surface at the base of the sprue

The surface in centimetres will be:

$$A[cm^2] = \ 0{,}000510204\ [m^2] \cdot \frac{1\ [m^2]}{1000[cm^2]} = 5{,}10204\ [cm^2]$$

Equation 12: Surface at the base of the sprue in cm

The diameter of the base of the sprue, therefore is;

$$A[cm^2] = \pi \cdot r^2[cm]$$

Equation 13: Area of the circumference

$$d[cm] = 2 \cdot \sqrt{\frac{A[cm^2]}{\pi}} = 2 \cdot \sqrt{\frac{5{,}10204[cm^2]}{\pi}} = 2{,}548\ cm$$

Equation 14: Diameter at the base of the sprue

The flow rate is the same in all the sprue at the top and the base.

$$Q_t[m^3/s] = Q_b[m^3/s] = A_b[m^2] \cdot \sqrt{g\left[\frac{m}{s^2}\right] \cdot 2 \cdot h} = A_t[m^2] \cdot \sqrt{g\left[\frac{m}{s^2}\right] \cdot 2 \cdot h`}$$

Equation 15: Flow rate defined by the surface and height

It possible, therefore to establish a relationship

$$\frac{{A_T}^2}{{A_B}^2} = \frac{h}{h`}$$

Equation 16: Correlation between area of the cone and height

The area of the cone at the top is;

$$A_T[cm^2] = \sqrt{\left(\frac{{A_B}^2[cm^2]^2 \cdot h[cm]}{h`[cm]}\right)} = \sqrt{\left(\frac{5{,}10204\ ^2[cm^2]^2 \cdot 0{,}01[cm]}{[0{,}03cm]}\right)} = 9{,}315007991[cm^2]$$

Equation 17: Area at the top of the cone

Therefore, the diameter would be;

$$d_T[cm] = 2 \cdot \sqrt{\frac{A[cm^2]}{\pi}} = 2 \cdot \sqrt{\frac{9{,}315007991[cm^2]}{\pi}} = 3{,}44[cm]$$

Equation 18: Diameter of the sprue at the top

The diameters at the base and the top in meters are

$$d_T[m] = 3{,}44[cm] \cdot \frac{1[m]}{100[cm]} = 0{,}0344[m]$$

Equation 19: Diameter at the top of the sprue in meter

$$d_b[m] = 2{,}548\ [cm] \cdot \frac{1[m]}{100[cm]} = 0{,}02548[m]$$

Equation 20: Diameter at the base of the sprue

The volume of the sprue is:

$$V_s = \frac{1}{3} \cdot \pi \cdot 0{,}07[m] \cdot ((0{,}0344[m])^2 + (0{,}02548[m])^2 + 0{,}0344[m] \cdot 0{,}02548[m])$$

Equation 21: Volume of the sprue

Therefore, the time required for fill the sprue is

$$t[s] = \frac{V[m^3]}{Q[m^3/s]} = \frac{0{,}000242636[m^3]}{0{,}0001[m^3/s]} = 2{,}4263[s]$$

Equation 22: Time required to fill the parts and feeder`s cavities

Chequered of Chvorinov rule, using comparison

The modulus method is described in the casting handbook, and is based in the concept that the freezing time of a casting or a casting section can be approximated by using Chvorinov´s rule

$$t = k^2 \cdot \left(\frac{V_C}{A_C}\right)^2 = k^2 \cdot {m_c}^2$$

Equation 23: Time of solidification defined by Chvorinov`s rule

This concept aim was to not be necessary to calculate the actual solidification times instead of that it will be calculated the relative solidifications times.

The Chvorinov’s rule is simplified into this

$$t \sim \frac{V_C}{A_C}$$

Equation 24: Aproximation of the Chvorinov`s rule

The volume area ratio is the determined by the casting modulus

$$M_C = \frac{V_C}{A_C}$$

Equation 25: Module of the ration volume area

The solidification times of the risers are proportional to their modulus, this modulus should be bigger that the solidification modulus of the casting, according to the handbook it should be at least 1,2 times bigger.

$$M_r = 1{,}2 \cdot M_C$$

Equation 26: Ratio module of the feeders and the casting

4. Die casting

4.1. Die casting design

The objective of the die casting process is to produce three pieces for the Testing part in the Master guide. All these three pieces should be casted in the same mold. After a brainstorming and a research, the first design was implemented in CATIA.

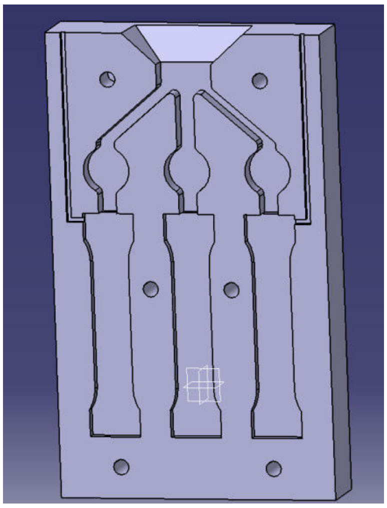


Figure 16: Die casting mold I

We have designed a few different designs combined with training CAD and learn all the functions.

In the first real and finished design the three pieces are been arranged vertical (Figure 16). The molten aluminium will get poured in the gate and flows down through the three tunnels in the three parts for testing. Also, there are 6 holes with a diameter of 10 mm to fix a plate on the mold to close it. Furthermore, in the mold, there got two channels implemented to allow the gas to escape.

After a feedback of the technical supervisor Mr. Balcaen, we modified the mold (Figure 17 – 19). The second solution does not have the gas vents anymore for the escaping gas. The gas can lead to an inferior quality of the final piece. In this case, the gas does not need to escape, because there is enough space over the pieces, which is getting cut off after the process. The shape of the tunnels was adjusted. Also, the plate to close the mold was designed in CATIA.

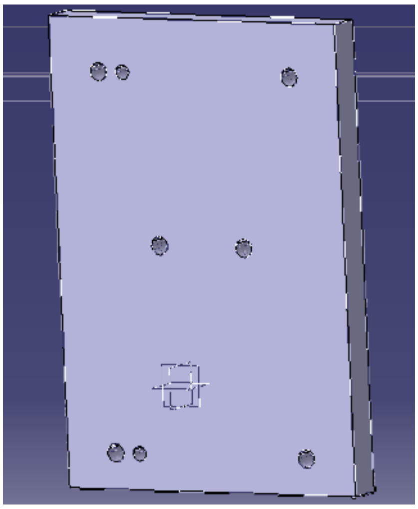


Figure 17:Die casting mold II plate

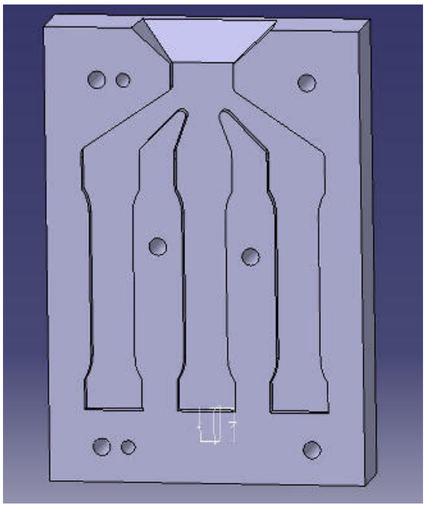


Figure 18:Die casting mold II mold

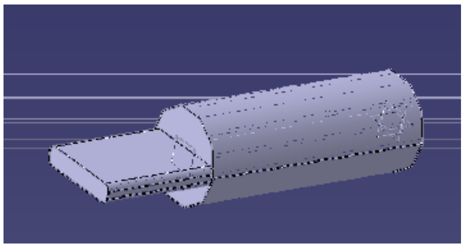


Figure 19: Die casting mold II bolt

The biggest different between the first and the second solution are the two smaller holes. The mold and the plate will be assembled with a bolt in the small hole on the top of the parts. The hole on the bottom of the parts is for a special bolt with one smaller end to make sure it fits in the hole, in case that the pieces change their dimension differently, because of the heating. After, the rotation is avoided, the mold and the plate can be fixed together with screws.

The next step was doing some calculations. After some more research, we realized that we must design the mold totally different (Figure 20). The parts should be getting filled from underneath. The feeder is way bigger than the parts to make sure that they don’t solidify before the parts are filled. We added a gas vent for every part again and we added some holes in the parts and the feeder. The aim of the holes is to create a solution to get the production out of the mold, when it is stuck. We will stick some bolts with a small tolerance in the holes before casting and after we can push the production out of the mold with hitting the bolts with a hammer on the other side of the mold.

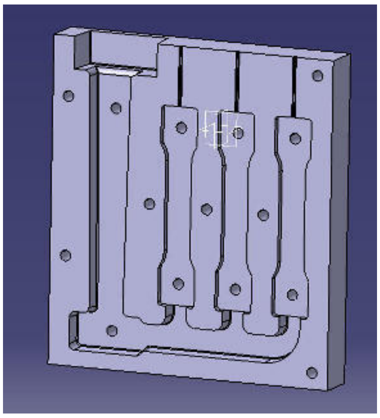


Figure 20: Die casting mold III

While trying to calculate the mold, there appeared some problems. We calculated the mold as good as possible, but together with our supervisors, we found out that the most companies who are using casting processes are getting their data with testing. So, we designed another mold to measure the solidification time (Figure 21). We deleted the parts for testing and designed a mold to cast just a simple square. The square is not getting filled from underneath like the testing parts in the design before. We will fill it from the left side. In the following section, you can still find the calculations for our final mold for the testing parts. We also created an excel file to calculate everything automatically.

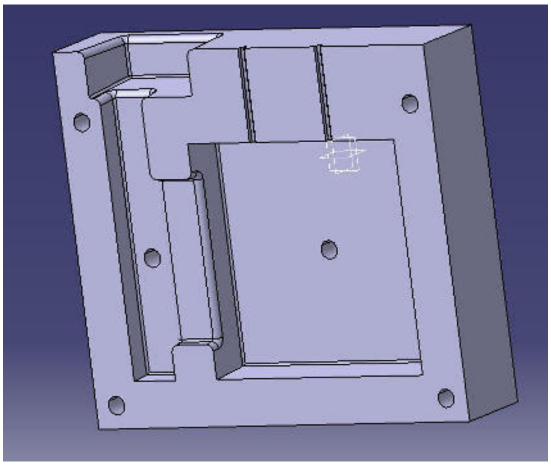


Figure 21: Die casting mold for solidification testing

4.2. Calculation for die casting mold

4.2.1. Objetive

The propose of this task is to define the necessaries parameters to design a mould according with the casting process physics and the requirements of the parts to make.

It will be necessary to define the aluminium alloy properties, and the dimensions and shape of the parts to be made.

Different solutions are presented and the goal is to decide which one the best and which one defines better the parameters of the mould.

The first way of make the calculations of different parameters needed for the design, even if in theory is correct, it does not present a solution suitable to be applied in a real case.

This situation is a real inconvenient for the achievement of the goal of the task of the mold design, therefore another alternative solution is presented.

4.2.2. Initial data

Some initial data is required at the beginning of the calculations. The properties of the materials used both the melted metal and the mould material used need to be known.

Aluminium alloy:

The aluminium alloy used in the process according to the requirements defined at the beginning of the project.

The aluminium alloy has a concentration of silicon around 12%, for define the properties of this alloy we use the data of a normalized aluminium alloy.

The aluminium 413 has a concentration of silicon between 11-13%, therefore we can use the proprieties of this alloy for our calculations.

Tm	Melting temperature	851,15 ºK
L	Latent heat of fusion	389000 J/Kg
ρ	Density	2666 Kg/m^3
C	Specific heat	963 J/(Kg·K)

Table 1: Aluminium 413 alloy properties

4.2.3. Mold material

The material for build the mold will be anodized steel, we will need the thermal properties of this material for the calculations.

K	Thermal conductivity	54
ρ	Density	7850 Kg/m^3
C	Specific heat of the metal	910J/(Kg·K)

Table 2: Anodized steel properties

4.2.4. Mold concept desingn

Different disposition of the parts cavities at the mold can be disposed.

Different solutions can be adopted according to the restrictions and the casting process.

We need to choose which one will be the most appropriate.

4.2.5. Paralel feeding

The first solution raised was to situate the feeder at the small side of the mould and make the cavities of the parts in a lower level.

This is a simple solution, that also allows an easy mechanization of the metal for built it.

Nevertheless, this design is not so common in casting moulds, it is a design that do not guaranties s the suitable filling of the cavities of the parts.

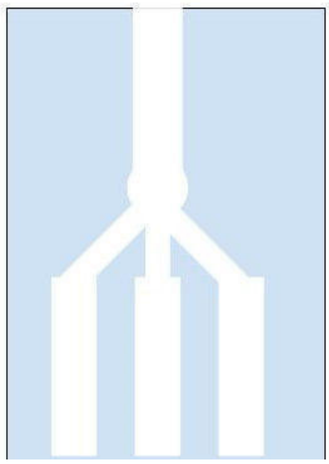


Figure 22: Parallel feeding concept design

4.2.6. Lateral feeding

Including a feeding system and a pouring cup in the die mold casting is a habitual practice. The addition of this elements to the die casting mould, makes that the melted metal flows in a better way into the parts cavities.

According to the designs that appears at the casting handbook, this is a more adequate solution than the parallel feeding.

This handbook also enhances that to make the filling more stable its recommendable to add into the design an inverse sprue for this lateral feeding.

With this design, we make sure that the sprue and the runner will be filled before the parts cavities starts to be filled. This will establish the flow conditions and will reduce the turbulences.

A design consideration for this solution is that the total cross-sectional area of the ingrates should be smaller than the cross-sectional of the runner (or inverse sprue in this design).

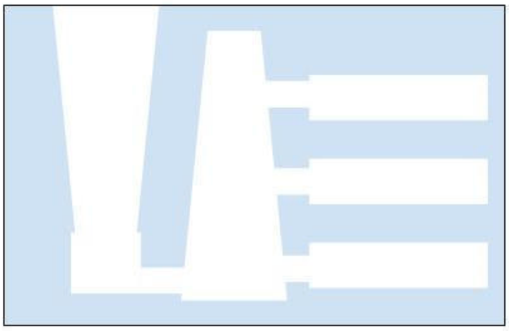


Figure 23: Lateral feeding design concept

4.2.7. Lower feeding

A simpler way to fill all the cavities of the mould is doing it from the inferior position.

This way allows to simplify the calculus needed for describe the mould design dimensions and in turn makes easier the mechanization of the metal for manufacture the mold.

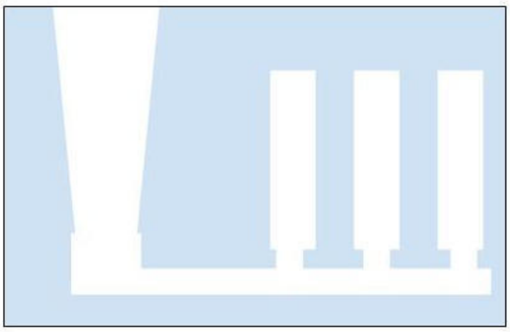


Figure 24: Lower feeding concept design

4.2.8. Calculations procedure

Some steps needed to be follow for define all the variables necessaries for design the die mould casting.

The methodology described in this section is based in theatrical assumptions, therefore the result will be also theatrical.

Even some of the results obtained are not suitable to be applied in the real design, those can be compared with results obtained by an experimental methodology.

The main variables needed to by described by these calculations are the diameters of the feeders and runners

4.2.9. Time of solidification

The first variable needed to be defined is the time that takes the melted metal in solidifies when it goes into the cavity of the part to know what is the time necessary for fill all the cavity.

The time of solidification can be determinate by Chvorinov´s rule, a mathematic equation that relates the volume and the surface area of a casting part.

This rule is based in the principle that says that for a big volume and small surface the part will solidify slower, and for a small volume and a big surface the part will solidify faster.

$$t[s] = B[\frac{s}{m^3}] \cdot \left(\frac{V[m^3]}{A[m^2]}\right)^n$$

Equation 27: Chvorinov`s rule equation

n, is a constant that use to take the value of two but also can be between 1.5 and 2.

B is a constant that depends on the proprieties of the metal casted and the proprieties of the mold.

$$B = \left(\frac{\rho_m \cdot L}{(T_m - T_0)}\right)^2 \cdot \left(\frac{\pi}{4 \cdot k \cdot \rho \cdot C}\right) \cdot \left(1 + \left(\frac{C_m \cdot \Delta T_S}{L}\right)^2\right)$$

Equation 28: B constant equation for Chvorinov`s rule

ρ_m; density of the metal (in [kg·m^{-3}])

L; latent heat of fusion (in [J·kg^{-1}])

T_m; melting or freezing temperature of the liquid (in kelvins),

T_0; initial temperature of the mold (in kelvins)

k; thermal conductivity of the mold (in [W·m^{-1}·K^{-1})])

ρ; density of the mold (in [kg·m^{-3}]),

C; specific heat of the mold (in [J·kg^{-1}·K^{-1}])

C_m; specific heat of the metal (in [J·kg^{-1}·K^{-1}])

ΔT_S; $T_{pour} - T_m$= super heat (in kelvins)

4.2.10. Velocity at the base of the sprue

For calculate the velocity at the base of the sprue, Bernoulli equation should be used. The Bernoulli equation is applied between the top of the sprue and the base.

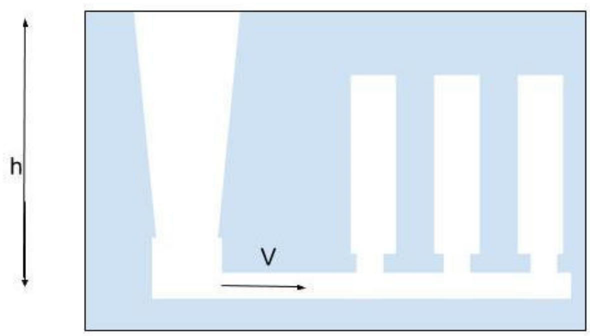


Figure 25: Height of the sprue and velocity diagram

$$h_1 + \frac{{v_1}^2}{2g} + \frac{P_1}{\gamma} = h_2 + \frac{{v_2}^2}{2g} + \frac{P_2}{\gamma}$$

Equation 29: Bernoulli equation betweet two points

We consider that P1 = P2 and is equal to the atmospheric pressure and v_1 negligible if it is compared it with v_2.

If this is taken in count and simplifying, the velocity at the base of the sprue is defined by this equation;

$$v[m/s] = \sqrt{h[m] \cdot 2 \cdot g[m/s^2]}$$

Equation 30: Velocity at the base of the sprue

4.2.11. Flow rate necessary to fill the cavities before them solidifies

Knowing the time of solidification of the parts and the volume of the parts cavities, it is possible to determine the flow rate needed to fulfil this requirement.

$$Q[\frac{m^3}{s}] = \frac{V[m^3]}{t[s]}$$

Equation 31: Flow rate defined by volume and time

When this flow is determinate, it can be used to know how the pouring of the metal should be done, by extrapolating this data into the whole mold cavities is possible to know the amount of aluminium needed melt and the time in which it must be done.

4.2.12. Areas of the feeders

According to the continuity equation, if the velocity is defined and changes depending of different heights, and the flow is constant the areas of the conducts were the melted metal flows should vary as the velocity does.

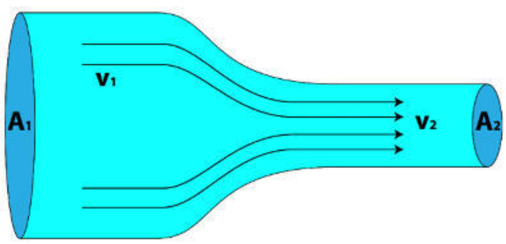


Figure 26: Continuity equation diagram

$$Q_1[m^3/s] = Q_1[m^3/s] = A_1[m^2] \cdot V_1[m/s] = A_2[m^2] \cdot V_2[m/s]$$

Equation 32: Continuity equation

In the diagram below, different areas of feeders for different speeds are defined for this mold figure. According to Bernoulli's theorem, the velocities in the upper positions will be smaller, and according to the continuity equation the areas will be larger.

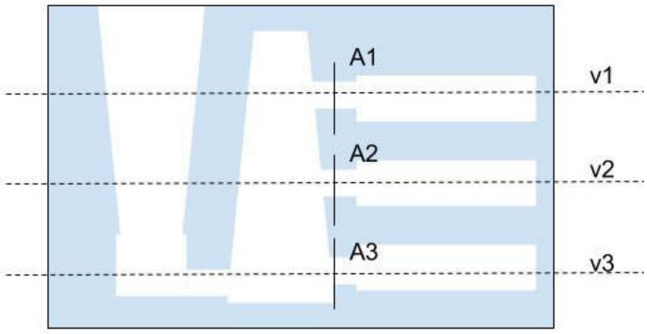


Figure 27: Explicative diagram of the continuity equation for a die casting mold

4.2.13. Dimensions of the feeders test by chvorinov´s module comparision

The modulus method is described in the casting handbook, and is based in the concept that the freezing time of a casting or a casting section can be approximated by using Chvorinov´s rule

$$t = k^2 \cdot \left(\frac{V_C}{A_C}\right)^2 = k^2 \cdot {m_c}^2$$

Equation 33: Chvorinov`s module in Chvorinov`s equation

This concept aim was to not be necessary to calculate the actual solidification times instead of that, it will be calculated the relative solidifications times.

The Chvorinov's rule is simplified into this:

$$t \sim \frac{V_C}{A_C}$$

Equation 34: Aproximation of Chvorinov`s rule

The volume area ratio is the determined by the casting modulus:

$$M_C = \frac{V_C}{A_C}$$

Equation 35: Chvorinov´s module of a casting part

The solidification times of the risers are proportional to their modulus, this modulus should be bigger that the solidification modulus of the casting. If it´s not the feeder will solidify before the casted part and it is possible that the melted metal doesn't fills all the cavities of the parts. According to the handbook the feeder´s Chvorinov´s module should be at least 1,2 times bigger than the casted part module.

.

$$M_r = 1{,}2 \cdot M_C$$

Equation 36: Ratio between the Chvorinov´s modules

4.2.14. Friction losses

Friction loses calculation. Darcy-Weisbach Equation:

Some friction is produced when the melted aluminium runs into the mold, and this loses should be consider.

This friction losses are determined by the velocity of the metal and the physical properties of the melted metal and the mould.

To compensate the impact of this loses wen can modify the areas of the feeders and gates to maintain the same flow rate.

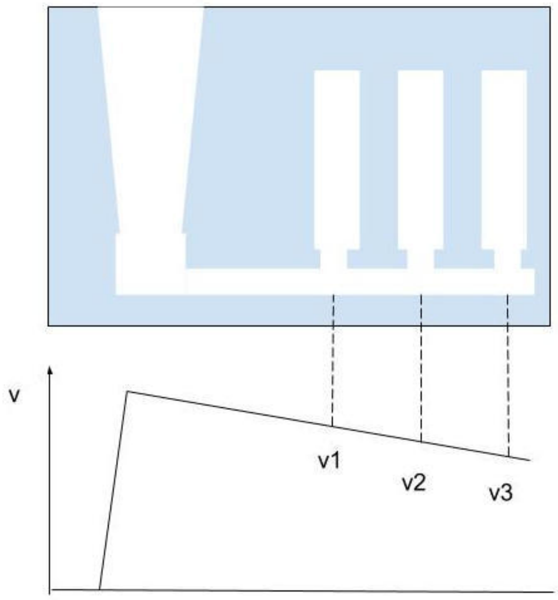


Figure 28: Diagram of the velocities variation caused by friction

This friction loses can be determinate by the Darcy´s -Weisbach equation.

$$hf\ [m] = f[adm] \cdot \left(\frac{L\ [m]}{Dh[m^2]}\right) \cdot \left(\frac{v^2\ [m/s]^2}{2g[m/s^2]}\right)$$

Equation 37: Loses caused by friction acording to the Darcy-Weisbach equation

hf; lost because of friction

L; length of the pipe; the feeder in this case

f; friction coefficient

Dh; hidraulic diameter of the pipe, the feeder in this case

v; velocity of the flow (average)

g; gravity constant

Depending the shape of the feeders Dh is defined by a different equation, a squared feeder is easier to mechanize but at the same time creates more losses since of friction.

$$Dh[m^2] \ = \ 4 \ \cdot \ (w[m] \ \cdot \ h[m]) \ / \ (2 \ \cdot \ (w[m] \ + \ h[m]))$$

Equation 38: Hydraulic diameter for a squared pipe

h, height of the pipe; the feeder in this case.

w; width of the pipe; the feeder in this case.

We consider that flow inside the die casting mold is a laminar one. To calculate the friction factor, we need to know the Reynolds number.

$$Re = \frac{v[m/s] \cdot Dh[m]}{V\left[\frac{\mathrm{m}^2}{s}\right]}$$

Equation 39: Reynolds equation

v; velocity of the flow (average)

Dh; hydraulic diameter

V; cinematic viscosity of the fluid

The cinematic viscosity of a fluid can be defined by the equation bellow:

$$V = \frac{\mu[\ \mathrm{kg}/(\mathrm{m} \cdot \mathrm{s})]}{\rho[kg/m^3]}$$

Equation 40: Cinematic viscosity

μ; dynamic viscosity$[\ \mathrm{kg}/(\mathrm{m} \cdot \mathrm{s})]$

ρ; density of the flow$[kg/m^3]$

Knowing the Reynolds numbers and the relative roughness it´s possible to find the friction factor at the Moody’s diagram.

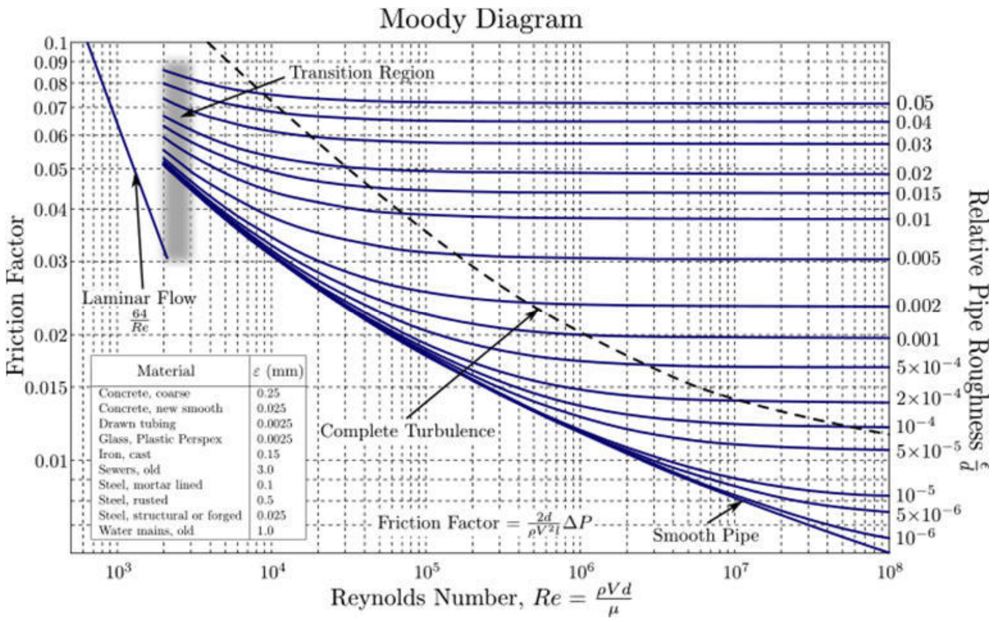


Figure 29: Moody´s diagram

Once the friction factor is determined the loses caused by the friction can be determined at the Darcy´s Weisbach equation.

It is possible, once it is known the friction losses to convert it into velocity, applying Bernoulli equation.

$$vf[m/s] = \sqrt{2 \cdot g[m/s^2] \cdot h_f[m]}$$

Equation 41: Velocity according to friction losses

4.2.15. Friction losess counteraction

The flow at the feeders should maintain continuous, but because frictional losses it does not.
To maintain the feeding of all parts cavities constant some modification needed to be made in the mold design.
Taking in count the continuity equation, for maintain the flow with a velocity decrease the area of the feeder should be increase proportionally.
The solution raised is to determine the velocity in two different distances of the feeder. With that is possible to create a linear progression of the velocity decrease and another for the increase of the diameter.

$$f_{\Delta v}(x)[m/s] = \frac{v_1[m/s] - v_2[m/s]}{d[m]} \cdot x[m]$$

Equation 42: Function that describes the velocity in a point of the runner

v_1; velocity of the flow at some point of the runner, taking in count friction
v_2; velocity of the flow at other point of the runner, taking in count friction
d; distance between these two points.

Applying this function to the continuity equation it is possible to determine a function that define the section area of the runner by the length.

$$fA(x)[m^2] = \frac{Q[m^3/s]}{\frac{v_1[m/s] - v_2[m/s]}{d[m]}} \cdot x[m]$$

Equation 43: Function that describes the section area at a point of the runner

With this equation, we can determine the design of the runner.

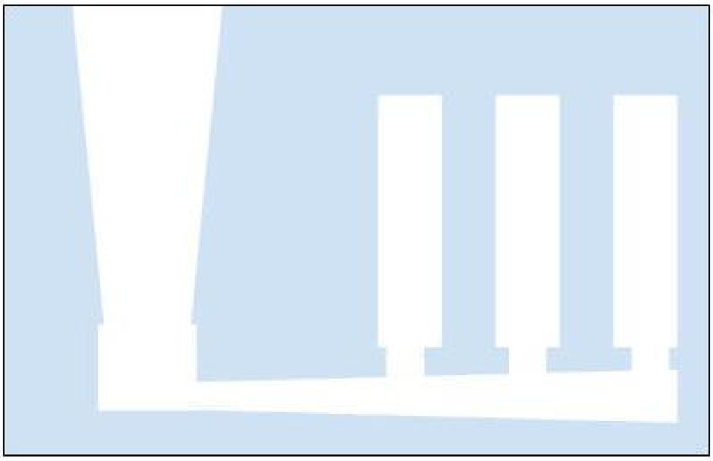


Figure 30: Runner design concept taking in count friction losses

4.2.16. Results

Applying the equations raised in the report some theoretical results are obtained, albeit this not seen to be suitable for being applied in a practical methodology.

The principal issue that appears in this result is founded at the solidification time equation, using Chvorinov´s rule.

It´s possible to find effortlessly on this that the Chvorinov’s constant cannot quadrate to a real case of solidification.

Therefore, without a realistic constant of solidification is not possible to continue with the process for defining the constrains of the design for build the mold.

Another solution must be raised in order to find out what is the time of solidification needed for the parts that are going to be casted.

4.2.17. Alternative solution

Another solution is raised to define the solidification constant that can be used for design and manufacture a die casting mold according the constrains and restrictions.

According there is no way to use a theatrical procedure to define this constant an experimental methodology should be described

5. List of Figures

6. List of Equations

7. List of Tables

Appendix 8

Research document

In research documents, we presentate the main literature we used to get some knowledge about the materials we are using and the different casting processes as well as for the calculations.

While working on the project it was necessary to gain theoretical knowledge. As a source of knowledge we used literature. The knowledge about aluminium was in Handbook of Materials for Product Design by Charles A. Harper. We found information about the properties of aluminium and silicon.

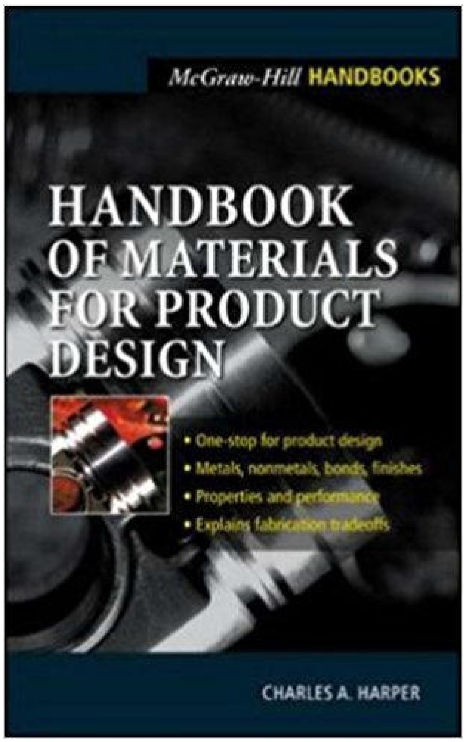


Figure 1:Handbook of materias for product design cover

Since the beginning of the project, we have been using a book, (ASM metals handbook volume 15 Casting) as a support for all the technical questions about casting processes. This "handbook is a complete guide about casting that includes theoretical aspects about casting including design calculations and methodologies.

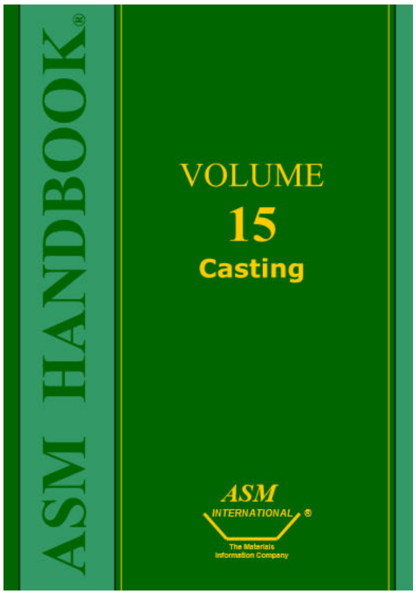


Figure 2: ASM handboook volume 15 casting cover

This book has been very useful, and we that has provided us some basis for the calculations and design part of the project. Although it describes in a detailed way all the casting processes, that was a good source for us to understand in what consists every method and what are the differences between them.

The book was especially clarifying for understand the die casting process and to know how to design the mold. At the gating design, apart of the handbook we could find all the information needed for that and wat physical aspects we need to apply. Different mold concepts are presented in the book depending of the gating system it was also useful to know which one was more suitable in our case.

Despite this handbook was useful it doesn't describe how to apply all the physical theorems in a real case, like Bernoulli and friction equations.

We had to search for another book that describes how to apply these equations into a casting case.

We have found at; "Ejercicios resueltos de tecnología mecánica", some examples of how these equation and physical assumption should be applied in castings molds.

Figure 3:Ejercicios resueltos de tecnologia mecánica cover

List of figures

Appendix 9

Theory

In the chapter Theory we provide some theoretical information. First, we explain the aluminium, alloys and fillaments and after, we give some knowledge about all the machines we used to perform the casting processes and metallographic examination in the laboratory of the ENIT.

Aluminium

Aluminium in the natural environment occurs together with other elements, mainly oxygen and silicone. It is in reddish, clayey bauxite sediments near the surface of the Earth. There are 92 natural elements in the earth's crust, the most of which is oxygen (47%), silicon (28%) and aluminium in 8%.
Aluminium is a chemical element with a mass of 26.98 atomic, metal, silver. We can distinguish eight isotopes of aluminium, most commonly aluminum-27. Aluminium, in a solid state, has a crystal structure focused on the face. It is characteristic that aluminium is lighter than other metals. The strength of aluminium alloy, however, is conducive to weak carbon steel and may approach up to 100 ksi (700 MPa). Aluminium is a popular material because of its high strength and light weight.
Aluminium is valued in the industry, it is easy to mold and manufacture. All methods used to form other metals can be used to mold aluminium. It is possible number of operations such as extrusion bending, rolling, drawing, forging, casting, machining and the spinning.
In order to reduce the melting temperature during welding and soldering, silicon is added to the alloys. Silicone also provides good flow characteristics, which in the case of forgings provides for a more complete filling of complex die shapes. An example of the use is the aluminium alloy 4043, which is commonly used for welding filler wire.

Cast Alloys

The casting alloys have higher proportions of the alloying elements than the alloys. For this reason, the casting rates are characterized by a heterogeneous structure that is generally less ductile than a more homogeneous structure of the molten alloys. The alloys are cast more silicon than the alloys formed to provide a fluid condition. Although the association aluminium alloy system uses four digits, such as the forged alloy system, most similarities end there. The cast alloy determination system has three digits followed by a decimal point followed by the next digit. The first digit indicates the alloying element. The other two digits indicate a stop or, in the case of commercial grade foundries, the level of purity. Last digit means product form - 1 or 2 for ingots (depending on level of contamination) and O for cast. Modification of the original stop is marked with a prefix (A, B, C, etc.) to the stop number.
The silicon addition provides excellent flowability of foundry alloys, as it does for wrought alloys. Thanks to that they are suitable for complicated, detailed castings. Silicone improves corrosion resistance. For example, stop A444.0 has low strength but good ductility.

Filaments

3D printing filament is the thermoplastic feedstock for fused deposition modeling 3D printers. There are many types of filament available with different properties, requiring different temperatures to print.

Polylactic

PLA is a popular material used in 3D printing. PLA is generated by the polymerisation of lactic acid originating from the fermentation of vegetable-derived sugars. Is completely biodegradable. It does not give off unpleasant odours. It is easy to use, provides excellent traction even with the use of a heated bed and is specially indicated for long lasting prints. It is possible to use typical traction methods such as varnish, tape or buckles. During the printing process, each layer must be sufficiently cooled before the print head settles another layer of molten fiber on the top. Thermal stress may occur during 3D printing. It is produced by the temperature unevenness at different points of the object. In 3D printing, this produces a bulge of the first layer due to the thermal difference between the bed (room temperature) and the filament (about 190-220 °C). When using PLA, heat stress is small and distortion is rare. The ideal print temperature is 205 ºC. Such value provides the best print quality and speed ratio.

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Figure 1: Fillament Polylactic

MOLDLAY

In our project, we decide use MOLDLAY filament to prepare object. MOLDLAY is new 3D printer filament, dedicated for two main casting methods: lost mold, lost wax casting and permanent mold casting.

The MOLDLAY filament is developed for casting and becomes completely liquid at 270°C. It is a wax-like thermoplastic which can be used for printing a casting mold and it features an excellent dimension stability and has almost no warping effect. At room temperature, the printed mold remains stiff and rigid. The filament becomes liquid (with a thin oil viscosity) when heated up to about 270°C thanks to some specially chosen types of oily paraffin. Material is designed for printing casting models. Is dimension stability. The material is stiff, rigid at room temperature. The best printing temperature is between 170°-180°. The Mold must be treated at approx. 270° in a baking oven. The wax flows restless out the mold, similar as hot paraffin.

Figure 2: Fillament Moldlay

Machine description

Naberthem K4/10

We used this melting furnace for the melting aluminium with addition silicon. This type of melting furnace is available for furnace chamber temperatures of 1000, 1300, or 1500 °C. This corresponds to melt temperatures about 80 °C - 110 °C lower.

Tmax 1000, 1300, or 1500 °C, with melt temperature about 80 °C - 110 °C lower is equipped in a size of 0,75, 1,5 or 3 litter. The crucible with integrated pouring spout of iso-graphite and delivery additional spout (not for KC) are included and mounted at the furnace for exact pouring.

Figure 3: Naberthem K4/10

Emptying of the crucible takes place by tilting system with gas damper.

It is possible to use this type of furnace as bail-out furnace without tilting device, e.g. for lead melting.

The furnace can set the temperature. The limit controller switches off the heating when the pre-set limit temperature has been reached and does not switch it on again until the temperature falls below the setting again.

Heracus K 750/2

In this type of the furnaces can reach operating temperatures up to 750 °C and are designed with intensive air circulation for rapid, even and controlled heat transfer to samples. The furnace is equipped with removable shelves made of heat resistant steel and are loaded through a sturdy tilting door. The outside surface of the door can also be used as a sample shelf or work surface. The work space volume is 55 litres.

The machine is equipped in the Thermicon P digital program controller, permits free programming up to 9 program steps. It also offers a set-actual-value indicator and an integrated timer for activating and deactivating heating (max. 99 hrs 59 min per program step).

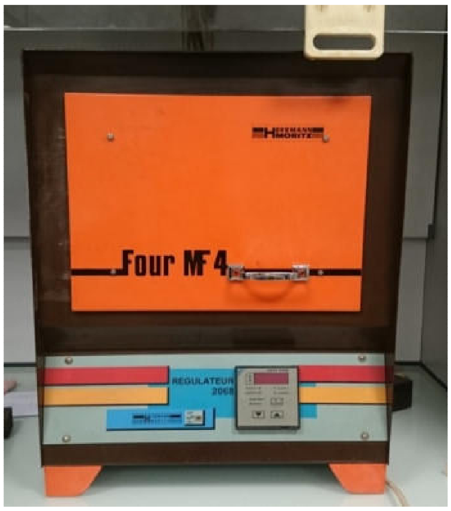

Figure 4: Heracus K750/2

Planopol 3 Struers

Figure 5: Planopol 3 Struers

The Planopol is a machine to produce smooth surfaces by lapping, grinding and polishing. The Planopol is driven by a two-speed motor. The table model is placed on the bench top on vibration-dampening rubber knobs attached to the steel frame. Also, there is a pipe for water, which is getting splashed on the disc for grinding or polishing. It is possible to regulate the speed of the rotation of the disc and the amount of water which is getting splashed on the disc. The machine has a loose protection ring to catches the water and shavings from the grinding process.

Mecatome 250

The MECATOME T300 is a rugged, powerful and reliable cutting machine that is easy to use and maintain. Cutting discs with a diameter of 250 and 300mm, combined with variable speeds, enable the best results when cutting all materials. Their construction allows for both the insertion of voluminous and bulky workpieces as well as the separation of bar material when the lateral covers are opened.

Figure 6: Mecatome 250

Appendix 10

Communication documents

The section communication documents is about the documents we used for the meetings with our technical supervisors and our management supervisors. It consists of an example for our Agenda and an example for our Compte-rendu.

Communication/Compte-rendu/Agenda

Proper communication between the team members and supervisors is essential for a proper functioning of the project. It is important to develop common principles with which all participants agree.

Communication between the project team and the supervisors based on meetings. Our meetings were held according to the needs, every or every second week. Two days before each meeting the project team sent an agenda by email, a list of different items discussed during a meeting. We also included information about the members of the meeting, the time and the place. After the meeting, a Compte-rendu was prepared, briefly describing the course of the meeting with a summary and actions to be taken in the future. Meetings were usually held in our EniOne office in building C. Most of the meetings were held separately from management and technical supervisors. Communication was also made by emails, most often this way was used to ask short questions. Communication between members of the team took place during meetings and by mobilephone.

Meeting Agenda
EPS ENI de Tarbes
Foundry process

1. Meeting information:

Objective:
Disscuss about the conclusions after Kick-off meeting.

Date: 28.03.2017
Time: 14.00
Location: EniOne's Room

Leader of the meeting: Justyna Kędziak
Note-taker: David Saez Diez
Attendees: Francois Grizet, Yannick Balcaen, Guillaume Mazenc, Justyna Kędziak, Oriol Fonellosa, Marvin Struß, David Saez Diez, Semih Yüksel

2. Agenda:

Items:

1. Redefining the priorities.
2. Defining the necessary tasks for each deliverable.
3. Gantt chart (defining an approximate time for each activity).
4. Redefining the risk matrix.
5. Date of the next meeting.
6. Closing the meeting.

COMPTE-RENDU
EPS ENI de Tarbes
Foundry process

Date: 20/03/2017 **Place:** ENI de Tarbes; EniOne's room **Scribe:** Justyna Kędziak

Participants :
Philippe Fillatreau
Justyna Kędziak
Oriol Fonellosa
Marvin Struß
David Saez Diez
Semih Yüksel

Purpose of meeting: Meeting 1, Screening of the project

Topics to discuss:
1. Discussion of the metods
2. Determining the rules of cooperation
3. Scope of the project

Discussion of the metods:

a) Wax Lost Mold Casting
   – CAD model: Design of the object for 3D printing
   – 3D printer (wax): Print to make a hollow space in the mold
   – Casting: Melt the metal and wait for solidify

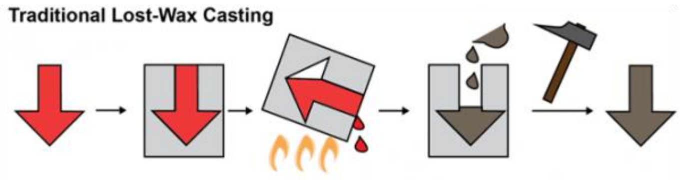

Figure 1.1: Steps of the Lost Wax Casting [1]

b) Sand mold
   – Creation or purchase of the object
   – Creation of the mold
   – Casting

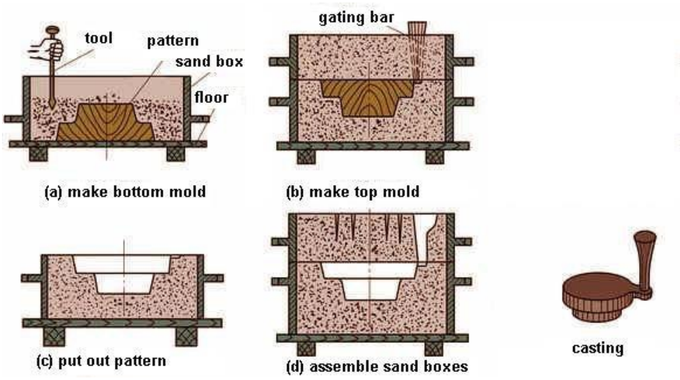

Figure 1.2: Steps of sand mold [2]

c) Die casting
   - CAD model: Design of the metal mold
   - Building or purchase of the mold
   - Casting process

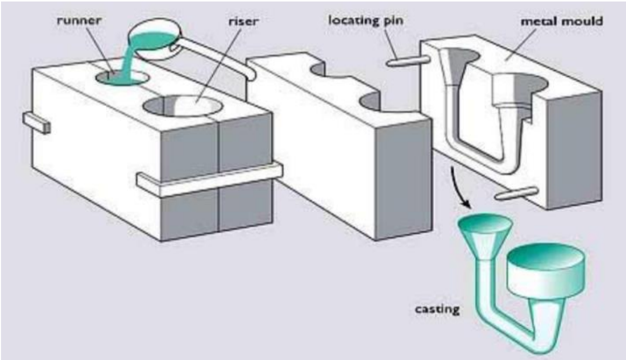

Figure 1.3.: Simulation of the die casting [3]

Summary

a) Characterization of the relation between methods and productions
b) Definition of the methods and activities in an accurate way (e.g. how many and which quality tests need to be done, decision about learning guide - how much time we will have?)

Determining the rules of cooperation:

We talked about time of our future meetings.

Summary

a) Preparation of "compte-rendu" after each meeting
b) Preparation and sending an agenda 3-4 days before meeting
c) Documents which going to be use during the meeting need to be send a few days before (weekends no counting)
d) Determinate a leader and a secretary for each meeting
e) To making explanations, define the context and keep it clear and simple
f) Using diagrams to define the process

Scope of the project:

We talked about the scope, clients, deliverables of our project.

Summary

a) Define the clients and all the documents needed
b) Define the deliverables (WBS method)

Bibliography:

1) http://static.projects.iq.harvard.edu/files/styles/os_files_large/public/sorotoolkit/files/cda-lostwax-1.png?m=1413397906&itok=KTrfaX6o
2) http://www.iron-foundry.com/blog.files/two%20cases%20molding.jpg
3) http://mc-cast.com/file/upload/Gravity%20Die%20Casting1.png